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Jnana Sangama, Belagavi – 590 018.

A PROJECTREPORT

on

"SMART ENERGY METER"

Submitted in partial fulfillment of the requirement for the award of the degree

Bachelor of Engineering

in

Computer Science and Engineering

by

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Certificate

Certified that the project work entitled "**SMART ENERGY METER**" carried out jointly by **Sanisha P S (1VI19CS091), Shravani R (1VI19CS104), Varsha M (1VI19CS122), T IRAM FATHIMA (1VI19CS115),** are bonafide students **of Vemana Institute of Technology** in partial fulfillment for the award of **Bachelor of Engineering** in **Computer Science and Engineering** of the **Visvesvaraya Technological University, Belagavi** during the year 2022-23. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the said degree.

Supervisor	**HOD**	**Principal**
Mrs.Rashmi R	Dr. M. Ramakrishna	Dr. Vijayasimha Reddy. B. G.

Submitted for the university examination (viva-voce) held on ……………………….

External Viva

Internal Examiner	**External Examiner**

1.

2.

DECLARATION BY THE CANDIDATES

We the undersigned solemnly declare that the project report “SMART ENERGY METER” is based on our own work carried out during the course of our study under the supervision of ‘Mrs. Rashmi R’.

We assert the statements made and conclusions drawn are an outcome of our project work. We further certify that,

a. The work contained in the report is original and has been done by us under the general supervision of my supervisor.

b. The work has not been submitted to any other Institution for any other degree/diploma/certificate in this university or any other University of India or abroad.

c. We have followed the guidelines provided by the university in writing the report.

d. Whenever we have used materials (data, theoretical analysis, and text) from othersources, we have given due credit to them in the text of the report and their details are provided in the references.

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ABSTRACT

The Efficient energy utilization plays a very vital role for the development of smart grid in power system. So, proper monitoring and controlling of energy consumption is a chief priority of the smart grid. The present energy meter system has few problems associated to it. To solve these problems, a smart energy meter module is proposed based on Internet of Things. The proposed smart energy meter module is an add on module that controls and calculates the energy consumption using ESP 8266 12E, a Wi-Fi module and uploads it to the cloud from where the consumer or producer can view the reading. The current system can be minutely modified to implement the proposed meter. Therefore, energy consumption and computation by the consumer becomes much easier and controllable. The use of smart meters to measure and report energy consumption enables utilities and energy distributors to manage their supply and demand in real time. The main benefits of smart metering systems are lower costs, higher reliability, reduced tampering and less carbon emissions. SEM Module enables the vision of a smart grid it ensures more accurate energy measurement and lower power consumption. This system also helps in detecting power theft. Thus, this smart meter helps in home automation using IoT.

Keywords: Energy consumption, electricity, energy distributor, power, energy meter

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LIST OF ABBREVIATIONS

1. AC : Alternating Current
2. ACS : Aerial common sensor
3. Amps : Ampere
4. BT : Bilateral triode
5. DC : Direct current
6. EEPROM : Electrically erasable programmable read only memory
7. EMF : Electro motive force
8. GPRS : General packet radio service
9. GSM : Global system for mobile
10. ICs : Integrated circuits
11. IOT : Internet of Things
12. LDO : Low-dropout
13. LM : Linear monolithic
14. MCU : Microcontroller unit
15. OLED : Organic light emitting diode
16. PLC : Power line communication
17. SEM : Smart Energy Meter
18. SMPS : Switch mode power supply

10\. USB : Universal serial bus

Chapter 1

INTRODUCTION

In the era of smart grids, smart metering entails not only the measurement of electricity, gas, water or heat consumption, but also communications from meter to data concentrator, or cloud. Real-time reporting of energy consumption directly to consumers improves consumer awareness, leading to waste reduction and lower expenses.

The use of smart meters to measure and report energy consumption enables utilities and energy distributors to manage their supply and demand in real time[1]. The main benefits of smart metering systems are lower costs, higher reliability, reduced tampering and less carbon emissions.

Smart Energy Meter Module enables the vision of a smart grid it ensures more accurate energy measurement and lower power consumption.

A smart meter is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behavior, and electricity suppliers for system monitoring and customer billing. Smart meters typically record energy near real-time, and report regularly, short intervals throughout the day. Smart meters enable two-way communication between the meter and the central system[2]. Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier.

Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC). Wireless communication options in common use include cellular communications, Wi-Fi (readily available), wireless ad hoc networks over Wi-Fi, wireless mesh networks, low power long-range wireless (LoRa)[2]. Efficient energy utilization plays a very vital role for the development of smart grid in power system. So, proper monitoring and controlling of energy consumption is a chief priority of the smart grid. The existing energy meter system has many problems associated to it and one of the key problems is there is no full duplex communication. To solve this problem, a smart energy meter is proposed based on Internet of Things (IoT). The proposed smart energy meter controls and calculates the energy consumption using ESP 8266 12E, a Wi-Fi module and uploads it to the cloud from where the consumer or producer can view the reading. Therefore, energy analyzation by the consumer becomes much easier and controllable. This system also helps in detecting power theft[3]. Since the inception of electricity deregulation and market-driven pricing throughout the world, utilities have been looking for a means to match consumption with generation. Non-smart electrical and gas meters only measure total consumption, providing no information of when the energy was consumed. Smart meters provide a way of measuring electricity consumption in near real-time. This allows utility companies to charge different prices for consumption according to the time of day and the season[5]. It also facilitates more accurate cash-flow models for utilities. Since smart meters can be read remotely, labour costs are reduced for utilities.

Smart metering offers potential benefits to customers. These include,

- An end to estimated bills, which are a major source of complaints for many customers
- A tool to help consumers better manage their energy purchases smart meters with a display outside their homes could provide up-to-date information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills.

The energy meter available till now can only control and monitor the energy consumption of customers. Smart energy meter developed using power line communication (PLC) helps in power loss. The smart grid plays a great role in our present society. Several system using Arduino as well as microcontroller have been developed though the efficiency to measure power consumption drastically increased but due to cost effective it may not be considered as the suitable one[6]. The consumer cannot have a good and accurate track of the energy consumption on a more interval basis

The conventional meter has some of the common errors like

- Time consuming.
- Chance of theft.
- Error while taking the information and extra human involvement.
- Consumer cannot have daily update of his/her usage.

IoT based energy meter system mainly consists of three major parts i.e. Controller, Wi-Fi and Theft detection part. Whenever there is any fault or theft, the theft detection sensor senses the error and circuit response according to the information it receives[3]. The controller plays a major role in the system making sure all the components are working fine. Therefore, IoT can improve the performance and efficiency of the smart grid mostly in the three phases.

1.1 Scope

- Usually power companies provide very rough electricity usage data, the SEM Module provides data with a minute resolution. Knowing the household electricity usage allows to extrapolate statistics and can give precise numbers about the costs. Conversion of a existing energy meter into a smart energy meter using our S.E.M Module without having to replace it.
- Our Home/office/Factory power measuring and transmitting device has the capability to monitor and communicate with the web application to provide real-time information and data on our energy consumption.
- From the data, the application calculates the average normalized rate of consumption per hour, day, week, or month and draws a graph showing the consumption rate over time.

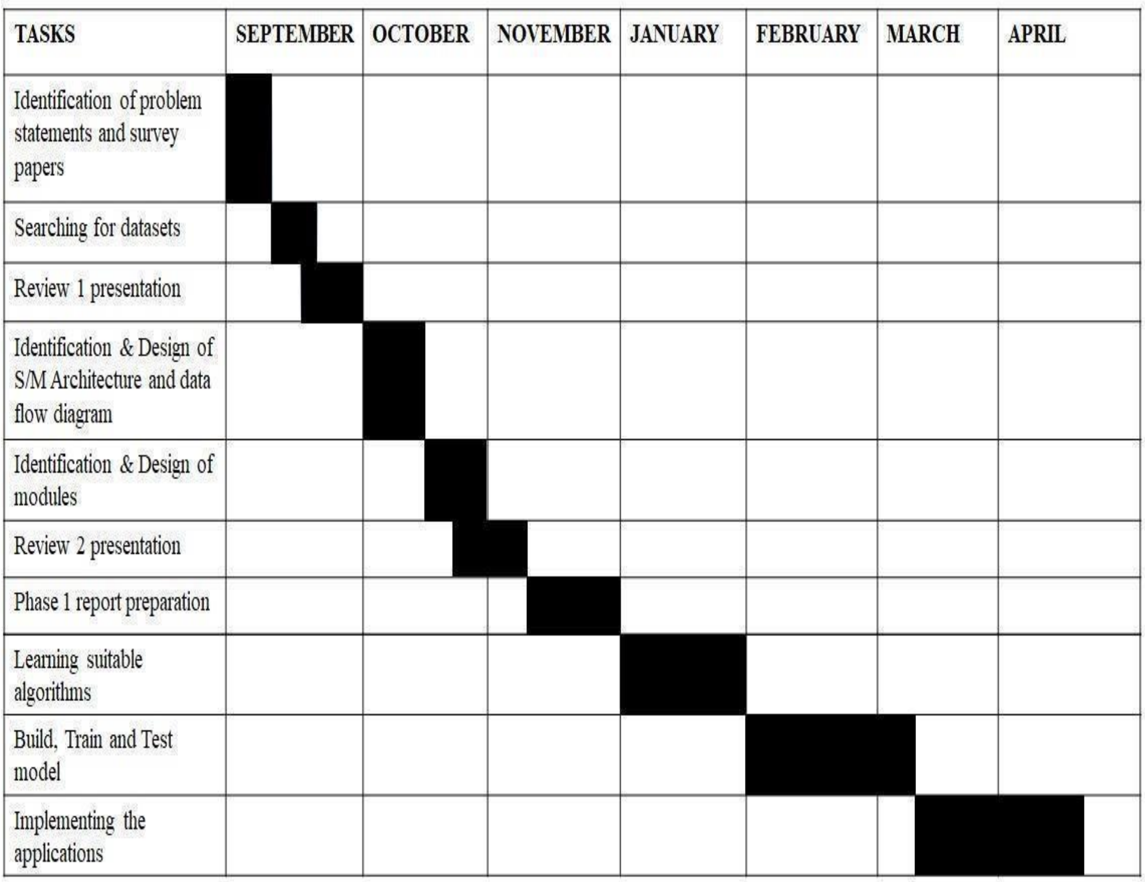
1.2 Objective

The main objective of this project is to track energy consumption by using our Smart Energy Meter (S.E.M) module offers potential benefits to householders.
These includes

- An end estimated bills, which are a major source of complaints for many customers.
- A tool to help consumers better manage their energy purchases stating that smart meters with a display outside their homes could provide up-to-date information on electricity consumption and in doing so help people to manage their energy use and reduce their energy bills.
- To design an add on module upgrade the functionalists of the current energy meters.

1.2.1 Plan of action for the project

Table 1.2.1 Timeline chart for the project



Plan of action for the project as shown in table 1.2.1 consists of the initial stage of analyzing what is required in the real world, the problems faced by electricity consumers, to draft a problem statement that will be helpful for every households and industries. The team identified the metrics to perform on. Later, the team identified the software and hardware requirements for the project, drafted a plan and collected 10 reference papers to gain information that is required to start the project. The team gained knowledge on IOT and Arduino and learned how to use them. The project was proposed to the college and reviewed by the panel lists. The documentation work was done, and we drafted the report for project phase 1. In coming phase, we develop a working prototype and checked the initial accuracy. We customized the prototype based on the results we got during the initialtest. The final testing is done after implementing all the changes. Lastly, we submitted the final report of the project.

1.2.2 Outline of the chapters

Chapter 1: Introduction

The chapter 1 is the brief introduction to the project Smart energy meter. The introduction contains the sub sections as scope and objectives of the project, and organization of the project work.

Chapter 2: Literature Survey

The chapter 2 is the literature survey which presents the list of base and reference papers referred during the project literature survey that is helpful for completion of our project. It presents 5 IEEE conference and reference papers that are proposed on the idea of smart energy meter. We have identified the advantages and limitations of each survey paper. This includes a comparative analysis of the papers to understand the how each proposal is different from the other.

Chapter 3: System Requirements

The chapter 3 consists of system specification including hardware and software requirements used in the proposed system and software requirements contains the software, IDEs and tools used to implement the system. It also includes the functional and non-functional requirements.

Chapter 4: Design Methodology

In this chapter we understand the system architecture and the dataflow diagrams to visualize the workflow.

Chapter 5: Module Description

In this chapter we elucidate the working of each module that is built to develop the system.

Chapter 6: System testing

In this chapter a standard test that ensures complete and fully integrated software product. The purpose of the system testing is to test the system specifications from end to end. System Testing takes, as your input, all integrated components that have passed integration testing.

Chapter 7: Results

In this chapter we have summarized all the work that we have done in the project.

Chapter 2

LITERATURE SURVEY

Here are a few papers which were Instrumental in the manner of references helping us in our journey of gaining knowledge and an insight on how we should proceed with our project, thus we would like acknowledge these sources. Here are a few to mention.

[1].Title: IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid.

Author: Bibek Kanti Barman and Shiv Nath Yadav

Year: 2018

Methodology: Proper monitoring and controlling of energy consumption.

Advantage:

- Development of smart grid in power system.
- Consumer or producer can view the reading at anytime.
- Helps in detecting power theft.
- Helps in home automation using IoT and enabling wireless communication.

Limitations:

- No full duplex communication.
- Existing system is error prone, labor and time consuming.
- Values that we get from the existing system are not precise and accurate.

In this paper, the efficient energy utilization plays a very vital role for the development of smart grid in power system. So, proper monitoring and controlling of energy consumption is a chief priority of the smart grid. The existing energy meter system has many problems associated to it and one of the key problem is there is no full duplex communication. To solve this problem, smart energy meter is proposed based on Internet of Things (IoT). The proposed smart energy meter controls and calculates the energy consumption using ESP 8266 12E, a Wi-Fi module and uploads it to the cloud from where the consumer or producer can view the reading. Therefore, energy analyzation by the consumer becomes much easier and controllable. System also helps in detecting power theft. Thus, this smart meter helps in home automation using IoT and enabling wireless communication which is a great step towards Digital India. With rapid growth and development, energy crisis has become a very big issue. An applicable system has to be made in order to analyze and control power consumption. Existing system is error prone, labor and time consuming.

The values that we get from the existing system are not precise and accurate though it may be digital type but it is always necessary that a concern person from the power department should visit the consumer house in order to note down the data and error can get introduced at each and every step. Therefore, the remedy for this solution is smart energy meter. The smart grid plays a great role in our present society. Tens of millions of the people's daily life will be degraded dramatically because of the unstable and unreliable power grid . Smart meter is a reliable status real time monitoring, automatic collection of information, user interaction and power control device . It provides a two way flow of information between consumers and suppliers providing better controllability and efficiency. It provides real time consumption information providing energy consumption control. Whenever the maximum load demand of customers crosses its peak value, the supply of electricity for thecustomers will be disconnected with the help of smart energy meter . In ideal environmentwith normal work load condition, the life span of the smart meter is about 5 to 6 years . But in reality smart energy meter suffers environmental issues and decreases its life span with abnormal consumption of energy.

[2].Title: GSM Enabled Smart Energy Meter and Automation of Home Appliances.

Author: Himshekhar Das, L.C.Saikia

Year: 2015

Methodology: Design of simple prototype of smart energy meter using global system for mobile communication.

Advantage:

- Smart energy system for the residential customers is developed and a smart switch board which can curtail the need to upgrade to smart appliances to make the system more economic.

Limitations:

- Proposed system was not economic.

Electrical utilities are suffering from huge losses due to power theft, inadequate usage of energy, unpaid bills, distorted power quality. Many viable solutions are proposed out of which smart energy metering, energy management system and smart home automation are some that seems to be potent enough. These technologies are presently used by developed countries. Under meter data acquisition system of Restructured Accelerated Power Development and Reform program (R-APDRP) scheme in the current year , India plans to develop Advanced Metering Infrastructure (AMI). But no effort has been made to develop an economic model for the customers which would play a key role in better acceptance of the scheme. In this paper, a smart energy system for the residential customers is developed and a smart switch board which can curtail the need to upgrade to smart appliances to make the system more economic. Further, a Virtual Instrumentation has been developed which can be operate in any computer to function as In Home Display (IHD)for Energy Management System (EMS). Smart metering system of different countries have been reviewed and smart meter system for residential have been developed in . It also demonstrates the effectives of In Home Display (IHD). Design of simple prototype of smart energy meter using global system for mobile communication (GSM) and Zig-Bee has been presented in. Design of an economic model of Smart Energy Meter for Ontario residential have been presented in. The present scenario of Smart grid pilots and key performance indicators have been investigated in . The feasible communication technologies for deployment in Advanced Metering Architecture (AMI) has been discussed and a cost effective Smart Energy Meter have been proposed in . An energy efficient and user convenient Smart Meter has been presented in. A communication network architecture for Home Energy Management System (HEMS) has been proposed in. A smart energy meter along with an iOS application for reporting power consumption, power generation and power quality parameters has been presented in. However, the investigations fail to target the practical challenges posed for implementation of Smart Energy Meter in India. Their work is limited to just design of economic model of Smart Energy Meter. In this paper, a smart energy system for the residential customers is developed and a smart switch board which can curtail the need to upgrade to smart appliances to make the system more economic.

[3].Title: Smart Energy Metering and Power Theft Control using Arduino & GSM

Author: Visalatchi S , Kamal Sandeep K

Year: 2017

Methodology: Concept and working of new automated power metering system.

Advantage:

- Detect and control the energy meter from power theft and solve it by disconnecting and reconnecting the service of a particular consumer.
- Power theft detection.

- Power consumption, power quality, and its accuracy can be monitored by the consumers directly in their mobile.

Limitations:

- It is quite impossible to check and solve out theft by going every customer’s door to door.

Energy theft is a very common problem in countries like India where consumers of energy are increasing consistently as the population increases. Utilities in electricity system are destroying the amounts of revenue each year due to energy theft. The newly designed AMR used for energy measurements reveal the concept and working of new automated power metering system but this increased the Electricity theft forms administrative losses because of not regular interval checkout at the consumer's residence. It is quite impossible to check and solve out theft by going every customer’s door to door. In the paper, a new procedure is followed based on microcontroller Atmega328P to detect and control the energy meter from power theft and solve it by remotely disconnect and reconnecting the service (line) of a particular consumer. An SMS will be sent automatically to the utility central server through GSM module whenever unauthorized activities detected and a separate message will send back to the microcontroller in order to disconnect the unauthorized supply. A unique method is implemented by interspersed the GSM feature into smart meters with Solidstate relay to deal with the non-technical losses, billing difficulties, and voltage fluctuationcomplication. This paper is the combined hardware advantage for both utility and the customer. Arduino, SSR, and GSM stationed Energy Meter for smart metering, power theftdetection, and voltage variation is built which is able to read and send data via. wireless protocol using GSM technology through GSM modem, capable of managing and controllingthe supply to that meter through SSR. In the case of power theft, defaulter meter line cutting/joining labor system is reduced. Power consumption, power quality, and its accuracycan be monitored by the consumers directly in their mobile. This process will reduce the labor work and human error in the distribution system and also protect the consumer equipment. This work is focused on BTM ESSs installed in end-users premises andassociated technologies, different billing and pricing policies, as well as their potential capabilities from both the system operators and end-users perspectives. Furthermore, a briefbut comprehensive overview of optimization solutions for BTM energy management problems and a quick summary of some BTM case studies are provided. Finally, challenges

in the realization of BTM systems in today's power system are explored .

[4].Title: Arduino Based Smart Energy Meter using GSM.

Author: Himanshu K. Patel, Tanish Mody, Anshul Goyal

Year: 2019

Methodology: System that removes human intervention in meter readings and bill generation

Advantage:

- The cost of system has been estimated to be less than the available smart meters, offering the same functionality.
- A user-friendly billing system with least human errors.
- This device enables the users to easily monitor and track their energy usage.

Limitations:

- Limited rate of data transfer.

India faces the issue of energy theft at a very large scale. This paper introduces a system that removes human intervention in meter readings and bill generation thereby reducing theerror that usually causes chaos and energy related corruption. The proposed system is implemented using a GSM shield module on microcontroller (Arduino) together with LDR sensor and relay. Existing metering system can be minutely modified to implement the proposed meter. The proposed scheme is to connect an LDR sensor with the blinking LED and send the data to microcontroller via GSM shield. RTC provides delay and acts an interrupt. The system includes a provision of sending an SMS to user for update on energy consumption along with final bill generation along with the freedom of load re-configuration via SMS. The disconnection of power supply on demand or due to pending dues was implemented using a relay. Hardware implementation results suggest that the accuracy of the proposed system is slightly greater than that of existing smart meters. The cost of system has been estimated to be less than the available smart meters, offering the same functionality. Bilateral communication between user and system sets it apart from the commonly available smart meters. 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 track their energy usage. The system proves to be advantageous in such a way that the user receives updates on consumption and can even disconnect the load from the supply in 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. Since this system can put India on the map of electrically-smart nations, there needs to be some work done to customize system for our country. For further implementations, the system can be exploited with some theft protections. Even though the system is designed to fit for domestic use as of now, the research for its economic feasibility on a commercial scale for industries is an unexplored arena. The industrial system could include power factor metering as well as control of power correction systems at different loading conditions. This will be additionally beneficial to the industries as it prevents them from penalties for low power factor implementation.

[5].Title: Futuristic Smart Energy Meter Design Based On Embedded Perspective.

Author: Ranjit T , Sivraj P

Year: 2018

Methodology: Computational needs of a futuristic smart energy meter and presents performance analysis of such an energy meter on a single core and multi-core microcontroller platform

Advantage:

- Additional functions such as smart appliance control, bidirectional communication between user and utility enabling user integration to the grid.
- Futuristic additional functions such as smart appliance control, bidirectional communication between user and utility enabling user integration to the grid energy meter.
- Helps in understanding the computational needs of a futuristic smart energy meter.

Limitations:

- Weak signals can disrupt the connections.

With the advancement of smart grid technologies for better electric power delivery a smart energy meter is no longer a simple energy measuring device, but has additional functions such as smart appliance control, bidirectional communication between user and utility enabling user integration to the grid etc. The paper studies about the computational needs of a futuristic smart energy meter and presents performance analysis of such an energy meter on a single or multi core and multi-core microcontroller platform with in Real - Time

Operating System(RTOS). Here the various applications in the for futuristic smart energy meter are identified, grouped into different classes, sensing, computation, communication and storage and implemented as modular tasks. The futuristic additional functions such as smart appliance control, bidirectional communication between user and utility enabling user integration to the grid energy meter implementation is done in LPC 1768 based embed microcontroller and LPC 4357 based MCB4357 board using Free RTOS. The performance of these implementations are compared, analyzed using Trace analyzer and real time debugger. This study will help in understanding the computational needs of a futuristic smart energy meter and also in the design of a best fit and light weight RTOS for smart energy meters. The use of smart energy meters will give the consumers a near real-time control over their energy bills. The design and implementation of a futuristic energy meter have been attempted through this work. The proposed meter will be able to measure current, voltage, power and calculate the energy consumption in a household and also to control various appliances as per demand. The data is used to monitor the energy consumption by means of two-way communication between provider and consumer. The futuristic energy meter is implemented in single core and double core microcontroller boards, with Free RTOS. From the performance analysis of the output, the importance of multiple cores and the need of areal time operating system in a smart energy meter is proved. This study also provides information for development of a sophisticated RTOS for future smart energy meters.

[6].Title: Advanced Smart Metering Infrastructure for Future Smart Homes.

Author: Rodriguez-Diaz , Mehdi Savaghebi

Year: 2015

Methodology: Integration of distributed energy sources and the demand control capabilities.

Advantage:

- Enables the utility to remotely connect and disconnect gas water and electricity.

Limitations:

- The system fails, if there is no network. because if there is no network the system can't send SMS.

Smart buildings and homes are becoming a key player in the future green and sustainable energy grid, due to the integration of distributed energy sources and the demand control capabilities. Advanced smart metering systems are required for the operation of the future smart grid. Smart metering systems allow to monitor the energy consumption of end- users, while provides useful information regarding power quality. This paper has shown the possibilities that can obtained from the integration of the advanced metering infrastructure with the concept of Smart Home. A whole real AMI system has been described, showing the information flow, the communication structure and the different variables that can be monitored in the system. Likewise, the in-home system composed of a wide range of Smart Devices and a central EMS has been illustrated, being the cornerstone to achieve substantial energy savings and showing the benefits of low-cost wireless PAN for the integration of appliances at home, leading to the future Internet of Things (IoT). Current works are focused on the development of an information interchange system between the central database and the individual users EMS, these results will be presented.

[7].Title: Development of Indigenous Smart Energy Meter adhering Indian Standards for Smart Grid.

Author: Sreedevi V S, Prakash Prasannan Jiju K

Year: 2020

Methodology: To enhance the energy supply, and several techniques, as load scheduling demand side management, intrusive-load management.

Advantage:

- The users could be aware of their whole energy consumption.

Limitations:

- Threat to the grid security or can bring up high maintenance costs for the utility. The information provided by these systems is used by the system operator to enhance the energy supply, and several techniques, as load scheduling, demand side management, non-intrusive load monitoring, can be applied for this purpose. This paper shows an advanced smart metering infrastructure for integration in future smart homes, where not only the electrical consumption is monitored, but also the gas, water, and heating. This paper shows an advanced smart metering infrastructure for integration in future smart homes ,herefore, by monitoring all energy systems in the building, the users could be aware of their whole energy consumption,and advanced control techniques can achieved by the Energy Management Systems (EMS).Smart meter made a revolution over conventional meters .

Intelligent inbuilt technologies had gained momentum worldwide as it favors both utility and consumer with its smart abilities. Smart meter paved the way for smart grid realization through AMI. CDAC develop smart meter in the way in accordance with Indian standards released by Bureau of Indian Standards (BIS). Since the development started from scratch, completeknow-how of smart meter could be achieved in hardware as well as software technologies. CDAC smart meters are adapted to amendments in the Indian standards that can occur in future. These in turn helps to get rid of any foreign agencies to intervene our system by any means that can pose a threat to the grid security or can bring up high maintenance costs for the utility. Thus indigenous development of smart meter paves the path with full authority and control for the revolution of smartgrid realization through AMI.

[8].Title: A Comprehensive Review of Smart Energy Meters in Intelligent Energy Networks.

Author: Qie Sun, Hailong Li, Zhanyu Ma, Chao Wang

Year: 2015

Methodology: Intelligent energy networks.

Advantage:

- To measuring energy flows, smart energy meters can exchange the information on energy consumption and the status of energy networks between utility companies and consumers.
- The significant increase in energy consumption and the rapid development of renewable energy.

Limitations:

- The cost for smart meters is also very large and distribution of the cost may be a problem.

The significant increase in energy consumption and the rapid development of renewable energy, such as solar power and wind power, have brought huge challenges to energy security and the environment, which, in the meantime, stimulate the development of energy networks towards a more intelligent direction. Smart meters are the most fundamental components in the intelligent energy networks. In addition to measuring energy flows, smart energy meters can exchange the information on energy consumption and the status of energy networks between utility companies and consumers. Furthermore, smart energy meters can also be used to monitor and to control home appliances and other devices according to the individual consumer's instruction. This paper systematically reviews the development and deployment of smart energy meters, also smart electricity metering smart heat meters, and smart gas meters. By examining various functions and applications of smart energy meters, as well as associated benefits and costs, this paper provides insights and guidelines regarding the future development of smart meters. It can be seen that technology will not be a problem, as soon as the development is not locked into just a specific type of technology. A more important issue affecting the development is the economic factor. In addition, the impacts on the environment during the whole process of development should also be taken into account. Globally, the most concerned environmental problem at present is climate change,while local ambient pollution is more critical for many developing countries. Therefore, thiscalls for effective policy instruments that can take the advantage of market as an important means to distribute resource and costs and benefits. For this purpose , very detailed scenarios, that is i.e. evolutionary forecasting scenarios (EFS) combined with back casting scenarios, could be established to create different possible roadmaps towards the future, where the important factors such as costs and benefits are used as criteria to optimize every pathway. Application of smart electricity meters can generate a significant amount of benefits, mainly for suppliers. The cost for smart meters is also very large and distribution of the cost may be a problem. Within the cost for smart meters, in- home display units account for a big proportion. Compared with benefits, costs have a larger impact on decision-making. A good business model is important for successful implementation of smart metering projects.

[9].Title: Household smart energy metering in Spain Insights from the experience of remotemeter reading in Alicante.

Author: H. March, Á.F. Morote, A.M. Rico, and D. Saurí

Year: 2017

Methodology: Remote meter reading.

Advantage:

- The reduction of energy consumption.
- Potential to engage users in more responsible behaviors.

Limitations:

- The cost of implementing these systems.
- The implementation complexity of the system.

Smart metering schemes emerge as a central feature behind the quest for more efficient and sustainable urban water supply networks in the 21st century. Despite the fact that under the concept of “smart meters”, we can find an array of different technologies, these all have in common the provision of more detailed, continuous and remote information of water use at the end-point of consumption (household, industry, etc.). Water-scarce countries, such as Australia, have been frontrunners in these initiatives. However, little academic analysis on the development of smart metering exists in other geographies and much less those providing significant qualitative insights from company managers and staff. Spanish Mediterranean urban areas, ridden with severe episodes of water scarcity, have also embraced these technologies, but we know comparatively little about their performance, as well as their benefits and costs. Beyond providing one of the first accounts and a qualitative analysis of the situation of urban smart metering schemes in Spain through the case of Alicante, where an ambitious remote reading of water meters is being implemented, our paper attempts to contribute to the debates on smart metering by providing an original perspective on the potentialities and limitations, as well as the costs and early benefits of these new schemes from a managerial perspective and from a Southern European perspective. According to the managers of Alicante’s water company AMAEM, the main advantages of remote reading of water meters revolve around the following issues the access to an in- depth and situated detailed knowledge of water use at the household scale for identifying patterns of consumption according to different variables the reduction of water consumption and the improvement of efficiency of the water network. The immediate detection of anomalous and excessive consumption and other environmental-related benefits. The reductionof costs(as some human actions will be no longer needed (such as manual meter reading) the possibilities to segment users and develop new pricing schemes that capture the oscillationsof water use throughout the day and the week the potential to engage users in more responsible behaviors. The immediate detection of anomalous and excessive consumption and other environmental-related benefits. All of these aspects are indicative of a shift of water companies towards the technological aspects of water management that help to increase the added value of their existing activities, instead of embarking on riskierventures.This, in our opinion, has not been especially emphasized in the literature and is very relevantfor areas such as Alicante and elsewhere in Mediterranean Spain, where water companies have to devote human resources to manually read (every 1–3 months) water meters for the household, commercial and industrial sectors.

[10].Title: A survey on behind the energy meter management systems in smart grid.

Author: S.Bayram and T.S.Ustun

Year: 2017

Methodology: Energy Storage System..

Advantage:

- Widespread integration of renewable energy resources to the power distribution system.
- Comprehensive overview of optimization solutions for BTM energy management problems.

Limitations:

- Random and damaging power spikes that can affect or even destroy electronics. The electric power industry is experiencing a paradigm shift towards a carbon-free smart system boosted by rising energy demand, depreciation of long-lived physical assets, as well as global environmental challenge. Recent advances in information and communications technology, as well as the widespread integration of renewable energy resources to the power distribution system, have introduced new opportunities and challenges for system operators and end-users alike. Energy storage systems (ESSs)can help make the most of the opportunities and mitigate the potential challenges. Hence, the installed capacity of ESSs is rapidly increasing, both in front-of-the-meter and behind- the-meter (BTM), acceleratedby recent deep reductions in ESS costs. This work is focused on BTM ESSs installed in end-users premises and associated technologies, different billing and pricing policies, as well as their potential capabilities from both the system operators and end- users perspectives. Furthermore, a brief but comprehensive overview of optimization solutions for BTM energy management problems and a quick summary of some BTM casestudies are provided. Finally, challenges in the realization of BTM systems in today's powersystemare explored, and potential research areas and progressive solutions for future studies are identified.

2.1 Comparative Analysis

Table 2.1.1 Comparative Analysis

Reference	Algorithm/ Technique	Platform used	Performance metric	Advantage	Drawback
1	Anomaly Detection frame work	Windows	Current	To detect network intrusion	Only label test instance
2	Alternate Mark inversion algorithm	Pulse code modulatio -n networks	Time	Make account maintenance more efficient for customer	May result in Reentrant collision of vehicles
3	Data Loading	Open source	Accuracy	ETL Process	Storage capacity
4	Three-Line	Windows	Temperature	Recording heating and cooling gradients	Time consuming
5	Power average ratio	Windows	Time	Daily electricity prediction	Multiple profiles generated
6	Incremental conductanc -e algorithm	Arduino	Power, Voltage	Ensuring the stable operation of the grid	Resting in mis- judgement
7	Maximum power point tracking	Arduino, Photovolt -aic(PV)	Power, Voltage	Maximize the power generated by PV	More expensive
8	Pulse Width modulation	windows	current	Reduce the power delivered by electrical signals	Bandwidth must be high for commun-- ication

Chapter 3

SYSTEM SPECIFICATION

A computer is made up of combination of two components, which is hardware and software. Both components are important and have its own functions and meaningful usages. The simplest definition of hardware is the thing which we can touch and software is the thing which we cannot touch but only feel.

3.1 Functional Requirements

These are the requirements that the end user specifically demands as basic facilities that the system should offer. All these functionalities need to be necessarily incorporated into the system as a part of the contract. These are represented or stated in the form of input to be given to the system, the operation performed and the output expected. They are basically the requirements stated by the user which one can see directly in the final product, unlike the non-functional requirements.

The Functional Requirements can be listed as follows:

- Consumer: Provide readings directly to the consumers. They update readings frequently enough to use energy saving schemes.
- Metering Operator: Allow remote reading by the operator, provide 2-way communication for maintenance and control.
- Commercial aspects of supply: Support advanced tariff system and remote on/off control supply and power limitations.
- Security Data Protection: Provide secure data communications and Fraud prevention and detection.

3.2 Non-Functional Requirements

Non-functional requirements: These are basically the quality constraints that the system must satisfy according to the project contract. The priority or extent to which these factors are implemented varies from one project to other. They are also called non-behavioral requirements. Non functional requirements are often incorrectly assumed rather than being explicitly defined by users. This can lead to problems towards the end of a project as the user expectations for non-functional requirements are not met. Many times, developers dismiss.

Non functional requirements as non-testable and therefore not enforceable. This lack of specificity in non-functional requirements sets the stage for conflicts between the users, systems architects, systems engineers and developers. For example, users expect software to start and run every time it is used however, the non-functional requirement of reliability may never have been explicitly specified.

Users expect new features to be added to a system and tested before they use them. Users assume the software is maintainable without an explicit declaration for maintainability. In many ways, they expect it to be an unwritten requirement or goal. In other words, users expect the system to be analyzable, changeable, stable and testable.

For example, smartphone users will switch apps to other apps if the energy consumed by the app is not efficient. Efficiency is therefore a non-functional requirement. Energy consumption may also be a functional requirement.

A nonfunctional requirement is an attribute that dictates how a system operates. It makes applications or software run more efficiently and illustrates the system's quality. Non functional requirements differ from functional requirements in many ways which can be mandatory and non mandatory, basic operations and additional features, intended purpose and customer expectations while it focus on users expectations such as performance.

They basically deal with issues like:

- Portability: Portability is a characteristic attributed to a computer program if it can be used in an operating systems other than the one in which it was created without requiring major rework. Porting is the task of doing any work necessary to make the computer program run in the new environment.
- Security: Security refers to the measures taken by any enterprise or organization to secure its computer network and data using both hardware and software systems. This aims at securing the confidentiality and accessibility of the data and network.
- Maintainability: The maintainability of a software system is determined by properties of its source code. This book discusses these properties and presents 10 guidelines to help you write source code that is easy to modify. In this chapter, we explain what we mean when we speak about maintainability.
- Reliability: Reliability is how well the computer system performs they require functions that it has been designed for and do them form without failure. This is

important because if the system is not reliable, then the system may not function.

- Scalability: With a scalable system, you will likely keep running the same software and merely add more hardware. There's nothing new about this idea, but the arrival of e-commerce has changed the way businesses go about - and think about - scaling computer systems.
- Performance: In computing, computer performance is the amount of useful work accomplished by a computer system. Outside of specific contexts, computer performance is estimated in terms of accuracy, efficiency and speed of executing computer program instructions.
- Reusability: Reusability In computer science and software engineering, reusability is the use of existing assets in some form within the software product development process these assets are products and by-products of the software development life cycle and include code, software components, test suites, designs and documentation.

3.2 Hardware Requirements

- ESP8266 12E
- ACS712 current sensor
- 0.96 OLED display
- BT136 Triac
- MOC3021 Opto Triac,
- MCT 2E
- LM1117 3.3V LDO regulator
- 5V SMPS Module

3.3 Software Requirements

- Programming IDE : Arduino 1.6.12
- Programming language: Embedded C
- Compiler : AVR GCC
- Programmer : arduino bootloader

Chapter 4

DESIGN METHODOLOGY

4.1 System Architecture

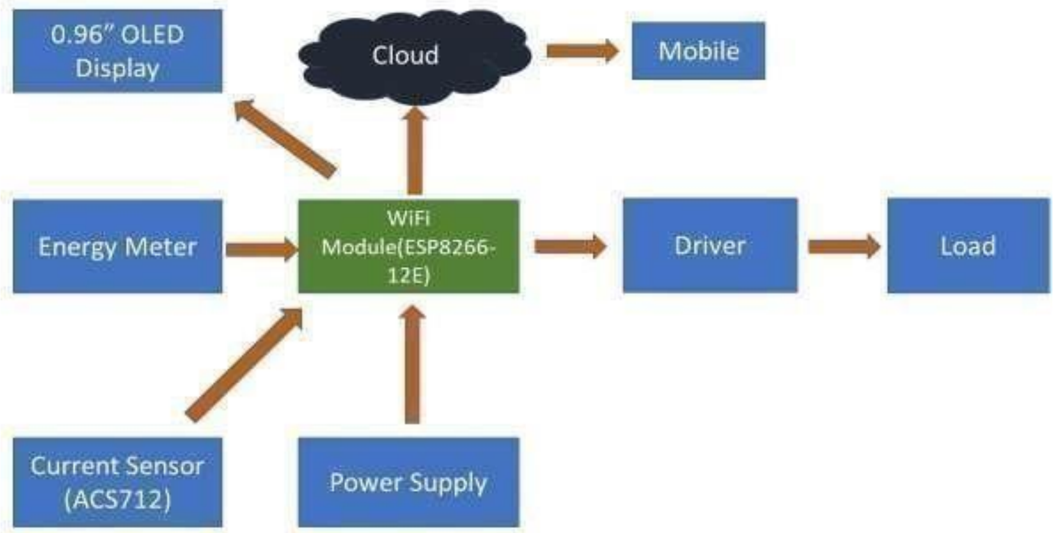


Fig 4.1 Design methodology of SEM module

Fig 4.1 shows the working of SEM module, as the energy meter is connected to ESP8266 12E via optocoupler. An OLED display is also connected to the system. In the driver circuit, ULN2003 is used to drive the relay in order to switch the loads.

- WiFi module: ESP 8266 12E is used here which is a programmable module with 80 MHz Microcontroller. As the module doesn't have separate USB port, we need to use an external USB to Serial adapter such as our FT232R Serial to UART Board to develop code using this module.

- OLED Display: 0.96-inch OLED display is used here which doesn't need backlight. The display can self-illuminate high resolution.

- OLED Display: 0.96-inch OLED display is used here which doesn't need backlight. The display can self-illuminate high resolution.
- Energy meter: The analog meter used here is of 3200imp/kwh. An optocoupler senses the led calibrated from the energy meter and sends its output to ESP 8266 12E.

- Optocoupler: It consists of an LED that produces infra-red light and a semiconductor photo-sensitive device that is used to detect the emitted infra-red beam.
- Optocoupler 4N35 is used here in order to sense the Cal impulse from the energy meter.
- Current Sensor: ACS712 current sensor gives precise current measurement for both AC and DC signals. These are good sensors for metering and measuring overall power consumption of systems. The ACS712 current sensor measures up to 5A of DC Or AC current. In this system it is used in order to measure the power theft.
- Driver: A relay driver is used in order to switch the load connected to the system. ULN2003 is used here.
- Load: A 100W bulbs are connected as loads to the system.
- Power supply: A 230V ac power supply is given to the system in order to power the energy meter. Wi- Fi module power is supplied by 5 V DC.
- The Wi-Fi module is programmed using Arduino IDE software in order to calculate the pulse from energy meter. It senses the pulse via optocoupler and sent the data obtained to the cloud using ESP 8266 12E.
- The LED blinks 3200 times for 1 unit. The blinking of LED is calculated for consumed power in units along with the cost of the units. The monitoring is done in every interval. The system also provides a power theft feature which is done using the current sensor connected to the system. Thus, the system doesn’t involve human providing less human error. The result obtained has been uploaded to an open IoT platform “Adafruit.io” which help us to store, collect, analyze data from Arduino and other supporting hardware. Initially, no information is transferred to the cloud via ESP 8266 12E (WIFI Module) as the load is not energies to the system. After connecting the load, information is transferred to the cloud using Wi-Fi module. Figure shows the initial data transferred to the cloud with connection of load. Thus, the system doesn’t involve human providing less human error. The result obtained has been uploaded to an open IoT platform “Adafruit.io” which help us to store, collect, analyze data from Arduino and other supporting hardware.
- The Wi-Fi module is programmed using Arduino IDE software in order to calculate the pulse from energy meter. It senses the pulse via optocoupler and sent the data obtained to the cloud using ESP 8266 12E.

The connections of the circuit are as shown in the figure below:

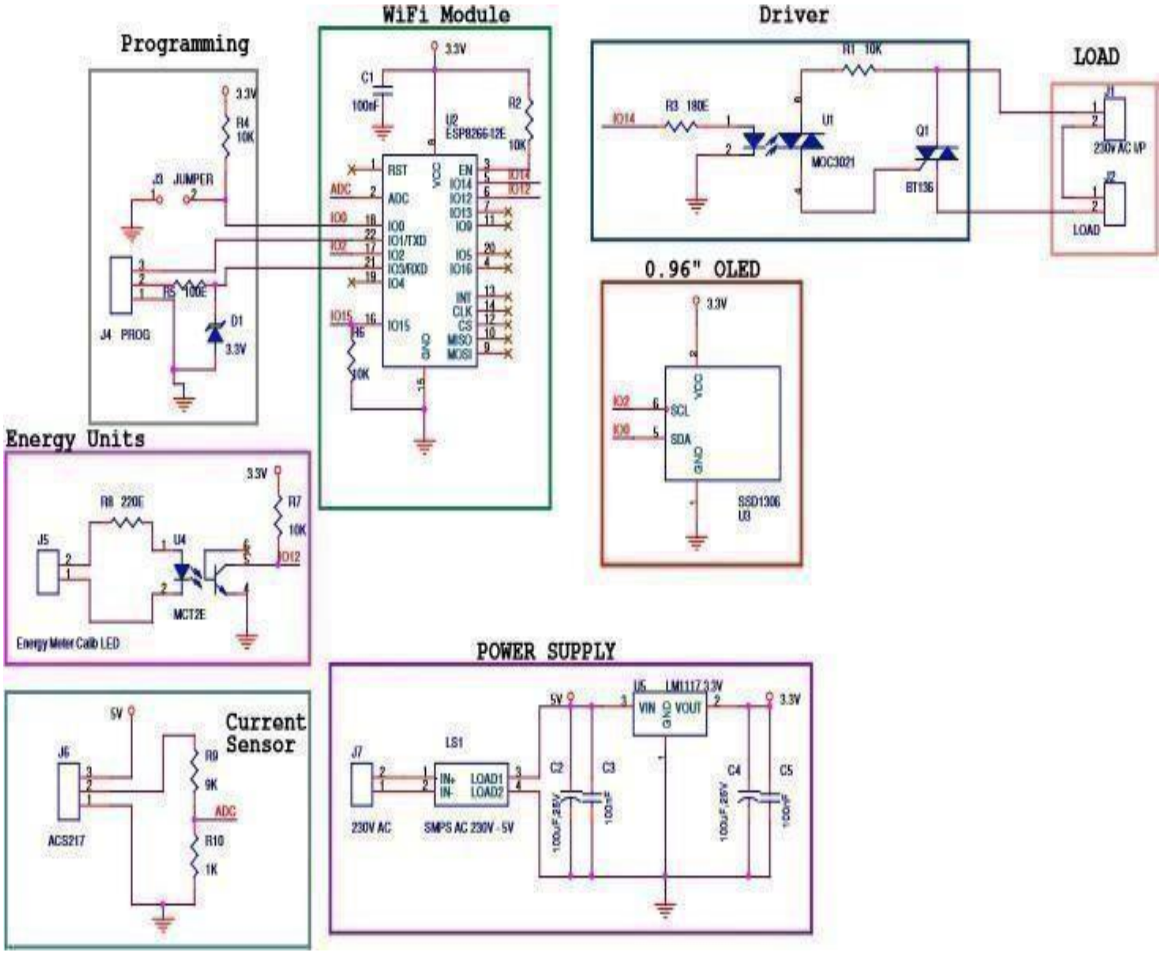


Fig 4.2 Connections of SEM circuit

Fig 4.2 shows connection of Smart Energy Meter (SEM) circuit on Arduino board, where the driver supplies power to load (i.e 200W bulb) that consumes this energy to glow up. The programme is implemented inside the Wi-Fi module. The driver is supplying 240v current.
The load is taking this 240 v current and with the help of SMPS module it is converting the 240V AC to 5V DC. Then the energy consumed is sensed by ACS712 current sensor, if energy consumed is below set threshold of 25 Kwh, then it is displayed on OLED display and is updated to cloud through ESP8266 wi-fi module so that consumer can be aware of energy consumed. The BT136-traic will resist the high flow of current through the circuit. If energy consumed by load is beyond set threshold then driver cut off supply to load and displays theft message on OLED display and unit of theft current consumed is updated to cloud through ESP8266.The MCT2E is used to send information from energy meter to the Wi-Fi module, from which the data is uploaded to the cloud. The consumer can check the data and keep tack of the power consumption.

4.2 Data Flow Diagram

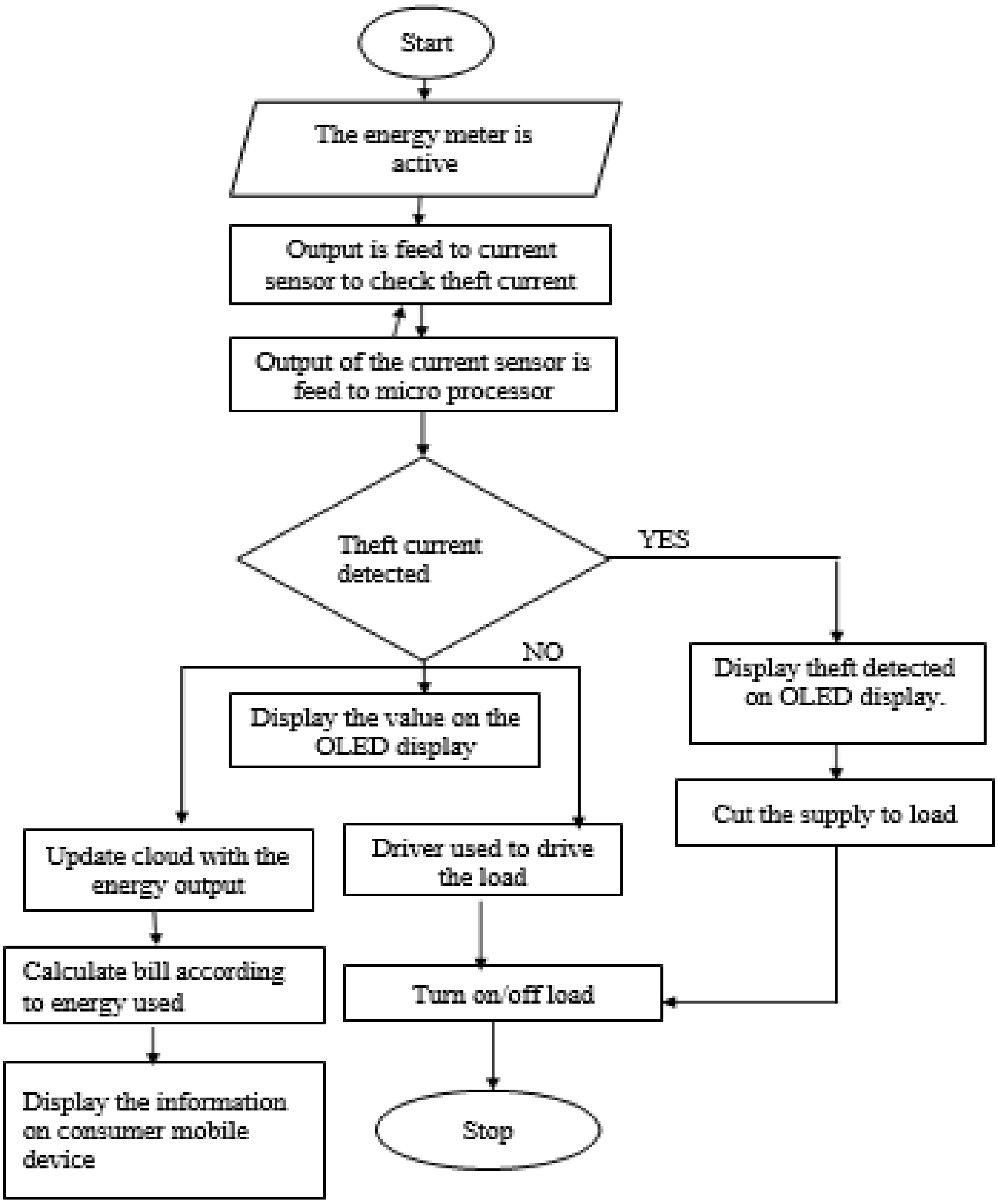


Fig 4.3 Flowchart of Automated Smart Cart

Fig 4.3, We observe that, on starting the system, the energy meter is active.Here the Output is feed to current sensor where it checks for any theft of current. Outputof the current sensor is then feed to micro-processor. Here, if the Theft current is detected,it displays theft defected on the Oled and then proceeds to cut the supply to the load whichin turn turns on/off the load depending on the scenario and stops. If no theft current is detected, it displays the value on the Oled display and updates the cloud with the energy output which calculates the bill according to the energyconsumed.

Chapter 5

MODULE DESCRIPTION

5.1 ESP8266 Wifi-Module


ESP8266

ESP-01 module by Ai-Thinker

Manufacturer	Espressif Systems
Type	32-bit microcontroller
CPU	@ 80 MHz (default) or 160 MHz
Memory	32 KiB instruction, 80 KiB user data
Input	16 GPIO pins
Successor	ESP32

Fig 5.1 ESP8266

Fig 5.1 shows ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. It has a wide temperature range: -40℃ to +125℃. ESP 8285-8M bit Flash embedded.

Features

- Processor: L106 32-bit RISC microprocessor core based on the Tensilica Xtensa Diamond Standard106Micro running at 80 MHz
- 32 KiB instruction RAM
- 32 KiB instruction cache RAM
- 80 KiB user-data RAM
- 16 KiB ETS system-data RAM
- External QSPI flash: up to 16 MiB is supported (512 KiB to 4 MiB typically included)
- IEEE 802.11 b/g/n Wi-Fi
- Integrated TR switch, balun, LNA, power amplifier and matching network

- WEP or WPA/WPA2 authentication, or open networks
- 16 GPIO pins
- SPI
- I²C (software implementation)
- I²S interfaces with DMA (sharing pins with GPIO)
- UART on dedicated pins, plus a transmit-only UART can be enabled on GPIO2
- 10-bit ADC (successive approximation ADC)

5.2 Pinout of ESP-01

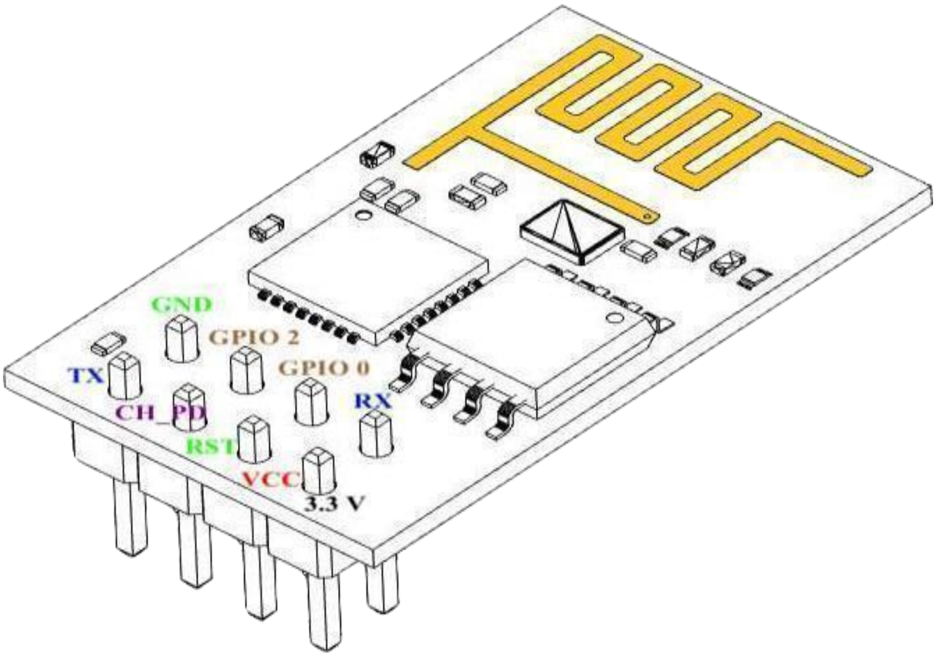


Fig 5.2 Pinout of ESP-01

Fig 5.2 shows Pinout for the common ESP-01 module:

- VCC, Voltage (+3.3 V; can handle up to 3.6 V)
- GND, Ground (0 V)
- RX, Receive data bit X
- TX, Transmit data bit X
- CH_PD, Chip power-down
- RST, Reset
- GPIO 0, General-purpose input/output No. 0
- GPIO 2, General-purpose input/output No. 2

5.3 ACS712 (Current sensor)

ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer as shown in Fig 5.3. A precise, proportional voltage is provided by the low-offset, chopper- stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging. The output of the device has a positive slope (>VIOUT(Q)) when an increasing current flow through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power loss.

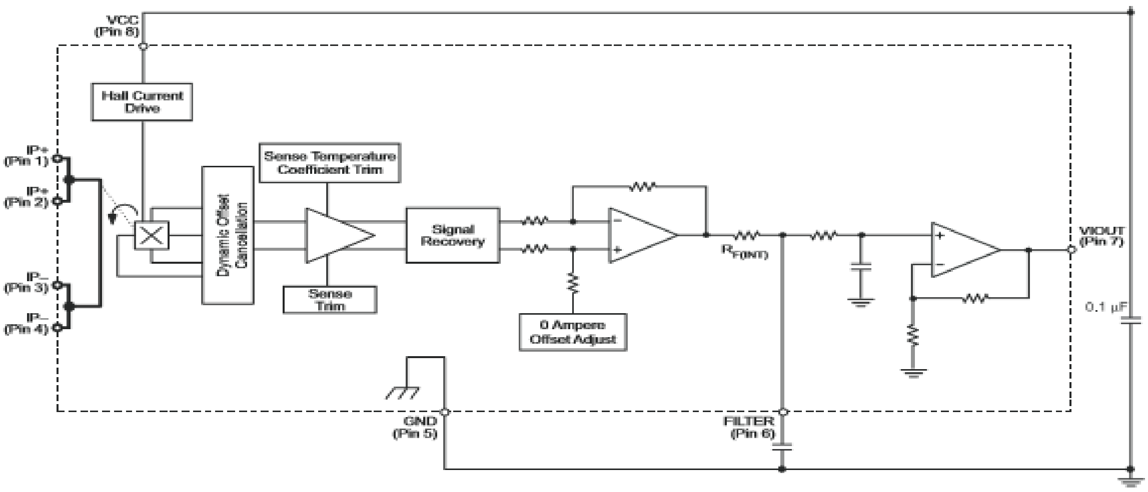


Fig 5.3 Functional Block Diagram of ACS712

Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% at TA = 25°C
- footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8

- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratio metric output from supply voltage

5.4 OLED Display

Fig 5.4 OLED(0.96')

Fig 5.4 is an organic light-emitting diode (OLED or Organic LED), also known as an organic EL (organic electro luminescent) diode, is a light-emitting diode (LED) in which the emissive electro luminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes typically, at least one of these electrodes is transparent.

Key Parameters

- Driver Chip : SSD1306
- Interface : 3-wire SPI、4-wire SPI、I2C
- Resolution : 128x64
- Display Size : 0.96 inch
- Dimension : 29mm*33mm Colors Yellow, Blue
- Visible Angle : >160°
- Operating Temp : (℃) -20℃~70℃
- Storage Temp : (℃) -30℃~80℃

5.5 BT136 Triac

Passivated triacs in a plastic envelope intended for use in applications requiring high bidirectional transient and blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching.

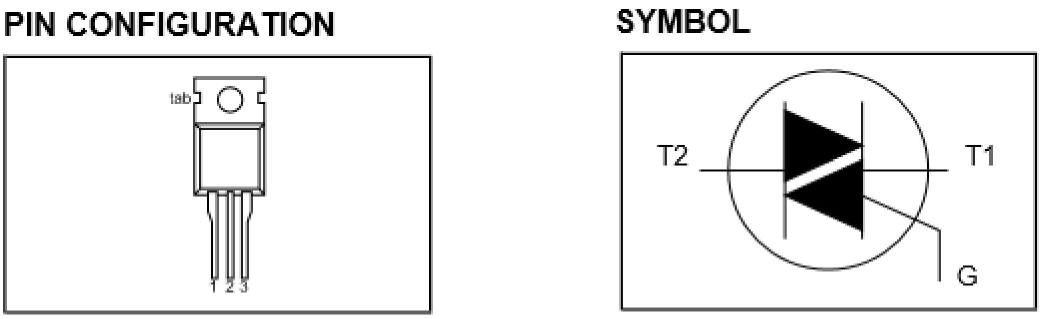


Fig 5.5 Pin Configuration and Symbol of Triac Pin Description

1. main terminal 1
2. main terminal 2
3. gate
4. tab main terminal 2

5.6 MOC3021 Opto-Triac

The MOC3021 was designed for interfacing between electronic controls and it's high power TRIAC to control loads for (AC Voltage) operations.

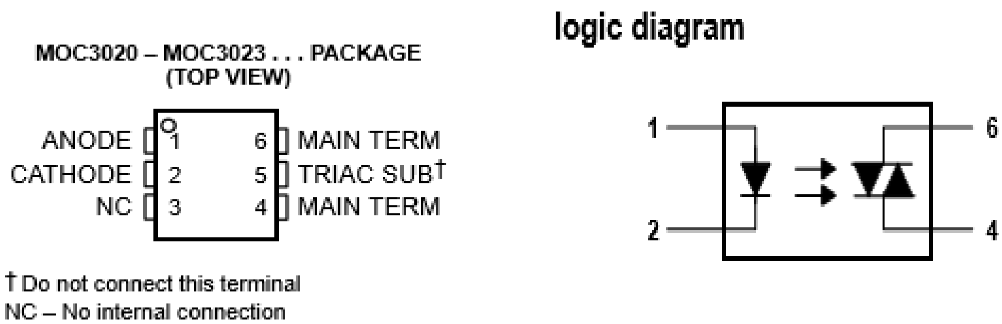


Fig 5.6 MOC3021Logic Diagram

Fig 5.6 , a small pulse (Clock pulse with 5 V range) is applied to its input that is pin1 and pin2. The light produced by this LED activates the TRIAC and that timepower is switched on. Mainly it is used to maintain isolation between low power circuits to high power circuits(that is a 5v pulse controls 3 phase load volts).

Drive Capacity

1. Off state output voltage = 400V.
2. RMS Forward current = 100mA.
3. Forward Peak current =1A.
4. Max power =200W.
5. Easy interface with ac 230v.

Pin Details

1. Anode
2. Cathode
3. NC (No Connection)
4. MT1 (Main Terminal)
5. NC (No connection)
6. MT2 (Main Terminal)

5.7 MCT2E

The MCT2E series opto isolators consist of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package. MCT2E is a phototransistor Optocoupler, as the name “phototransistor” suggests it has a transistor which is controlled based on light (photon). So this IC basically has an IR LED and a photo-transistor inside it. When the IR led is powered the light from it falls on the transistor and it conducts. The arrangement and pin-outs of the IR LED and the photo- transistor is shown below.

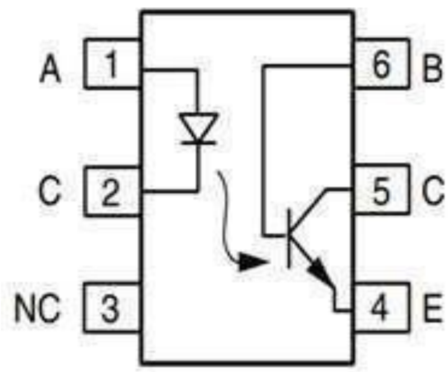


Fig 5.7 MCT2E Logic Circuit

Fig 5.7 , provides electrical isolation between two circuits, one part of the circuit is connected to the IR LED and the other to Photo-transistor. The digital signal given to the IR LED will be reflected on the transistor but there will be no hard-electrical connection between the two. This comes in very handy when you are trying to isolate a noisy signal from your digital electronics, so if you are looking for an IC to provide optical isolation in your circuit design then this IC might be the right choice.

Features and Specifications

- Input Diode Forward Voltage: 1.25V
- Collector-Emitter Voltage: 30V
- On-State Collector Current: 5mA
- Transistor HFE: 300
- Rise Time: 5us
- Fall Time: 5us
- Available as 6-pin PDIP with and without M-suffix

5.8 LM11173.3V LDO Regulator

LDO regulator means low dropout regulator. An LDO voltage regulator is just a DC linear voltage regulator which can be operated with a very small input-output voltage differential. This input output voltage differential is called dropout voltage. In simple words dropout voltage is the voltage dropped by the regulator circuitry alone for its working. For example, an LM2941 LDO voltage regulator has a drop out voltage of only around 0.5V, which means that in order to get 5 volts at the output you need to input only 5.5 volts where an ordinary 7805 linear voltage regulator has a dropout voltage of around 2V. This means that, in order to get 5V at the output of 7805 you need to input at least 7V.

LDO regulator working

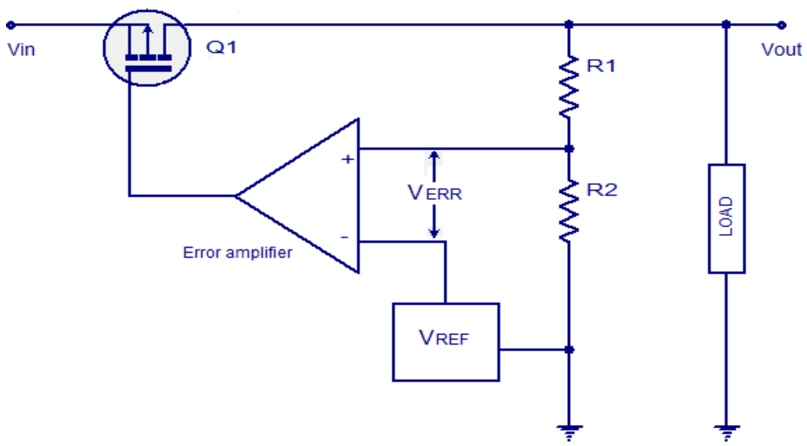


Fig 5.8 Schematic of a LDO regulator

Fig 5.8 shown above is the schematic of a typical LDO voltage regulator. The working principle of LDO regulator is just like that of an ordinary linear voltage regulator.The essential components of an LDO voltage regulator are a reference voltage source, error amplifier and series pass element (BJT or MOSFET). The voltage drops across the series pass element is controlled by the error amplifiers output in order to control the output voltage. For example, suppose the load current decreases and as results the output voltage tends increase. This increase in output voltage will increase the error voltage (VERR). The output of the error amplifier will increase, making the series pass element (P- Channel MOSFET) less conducting, which results in the reduction of the output voltage and the output voltage is brought back to the original level.

As it is said above the working of a LDO voltage regulator is similar to the working of an ordinary linear voltage regulator and the only difference is in the schematic topology of their internal circuitry. Ordinary linear regulators(7805, LM117, LM317 etc.) uses a common collector scheme while the LDO regulators use an open collector (termed as open drain if a MOSFET is used as the series pass element) scheme.

5.9 5V SMPS Module

Fig 5.9 5V SMPS Module

Fig 5.9 shows the 5V/3W SMPS Module (Hi-Link**)** is PCB mounted plastic enclosed isolated switching step-down power supply module. It can supply 5V DC from 120V AC - 230V AC and has a power rating of 3 Watt. This makes it perfect for small projects that needs a 5-volt supply from mains. There are many advantages for these modules, such as low temperature rise, low power, high efficiency, high reliability, high security isolation etc. It is widely used in smart home, automation and control, communication equipment, instrumentation and other industries.

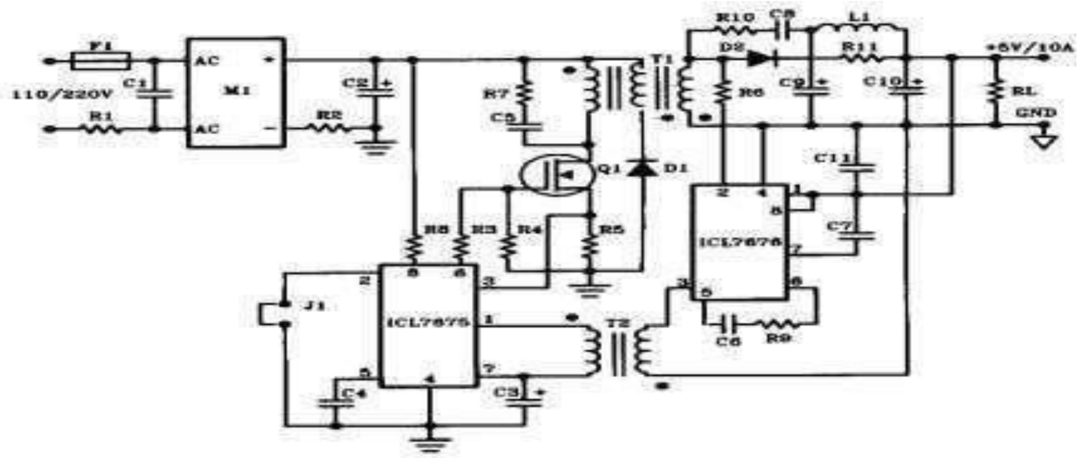


Fig 5.10 Circuit Diagram of 5V 10Amps SMPSS

Specifications of 5V/3W SMPS Module (Hi-Link)

- Meet UL, CE requirements,
- All voltage input (AC: 90 ~ 264V)
- Low ripple and low noise
- Output overload and short circuit protection
- High efficiency, high power density
- The product is designed to meet the requirements of EMC and Safety Test.
- Low power consumption, environmental protection, no-load loss <0.1W
- Operation Temperature: -20 — +60°C
- Store Temperature: -40 — +80°C
- Relative humidity: 5 — 95%
- Rated input voltage:100-240VAc
- Maximum input current: <0.2A
- Input current surge: <10A
- Maximum input voltage: 270VAc
- Input Low Voltage Efficiency: Vin=110VAc, Output full-load: 69%
- Input High Voltage Efficiency: Vin=220VAc, output full-load: 70%
- Long-term reliability: MTBF 100000h
- Load rated output voltage: +5±0.1
- Short-term maximum output current: 1000mA
- The maximum output current for a long time: 600mA
- Output ripple and noise: 50 mVpp Rated input voltage, full load. Using 20MHz of bandwidth, the load side with 10uF and 0.1uF capacitor.

5.10 Arduino 1.6.12

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, Mac OS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards. The source code for the IDE is released underthe GNU General Public License, version 2. The Arduino IDE supports the languages C andC++ using special rules of code structuring as shown in Fig 5.11. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main programloop, that are compiled and linked with a program stub main () into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program AVR GCC to convert the executable code into a text filein hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

Fig 5.11 Arduino IDE GUI

5.11 Adafruit.io

According to its developers, "Adafruit is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. Adafruit enables the creation of sensor logging applications, location tracking and seeing applications, and a social network is of things with status updates”. Adafruit was originally launched by io Bridge in 2010 as a service in support of IoT applications. Adafruit has integrated support from the numerical computing software MATLAB from MathWorks, allowing Adafruit users to analyze and visualize uploaded data using Matlab without requiring the purchase of a Matlab license from MathWorks as shown in Fig 5.12. Thing Speak has a close relationship with Math works, Inc. In fact, all of the Adafruit documentation is incorporated into the Mathworks Matlab documentation site andeven enabling registered Math works user accounts as valid login credentials on the Adafruit website. The result obtained will been uploaded to an open IoT platform “Adafruit which help us to store, collect, analyze data from Arduino and other supporting hardware.

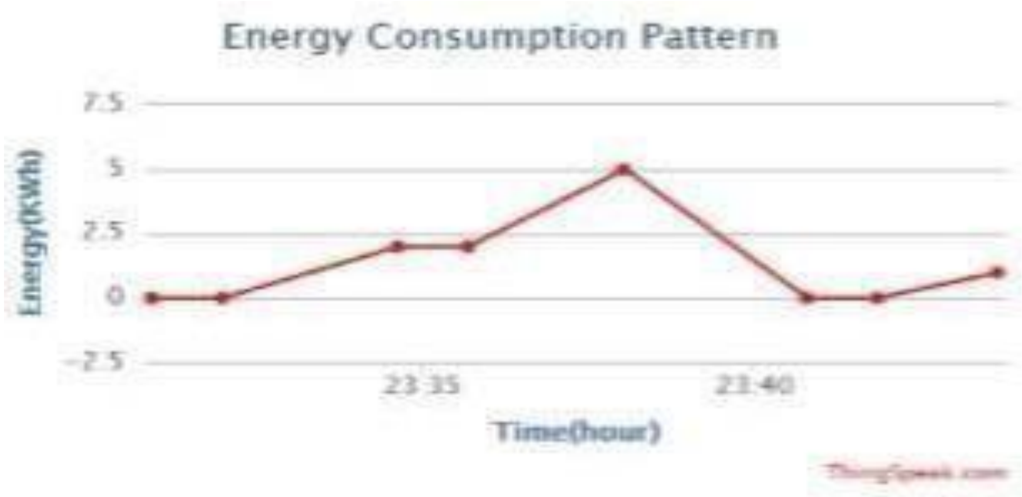


Fig 5.12 Data transferred to the cloud with connection of load

Chapter 6

SYSTEM TESTING

System Testing is a standard test that ensures complete and fully integrated software product. The purpose of the system testing is to test the system specifications from end to end. System Testing takes, as your input, all integrated components that have passed integration testing. System testing aims to detect errors both within "inter-assemblage". The real result is behavior that is produced or detected when a component or system is tested.It is done throughout the system in the context of the functional requirement specification (FRS) or system requirement specification (SRS), or both. It is also intended to test up to and above the limitations defined in the software or hardware requirements.

Table 6.1 Test cases

TEST CASE ID	INPUT DESCRIPTION	EXPECTED OUTPUT	ACTUAL OUTPUT	REMARKS
1	current	Bulb glow	Same as expected	pass
2	240 v ac current	5v dc current	Same as expected	pass
3	Power reading in OLED	Power in watts displayed	Same as expected	pass
4	Data from OLED to microprocessor	Data Transferred	Same as expected	pass
5	Data from ESP8266 Module to Cloud	Data Transferred	Same as expected	pass
6	Data access from Cloud	Successful Monitoring through Website	Same as expected	pass
7	If Theft Detected	Power Supply to the grid is off	Same as expected	pass
8	Message sent to Cloud	Data Access Through Phone	Same as expected	pass

The System testing is a process of analyzing and measuring the performance of the proposed System. Testing refers to executing the system to identify any faults, errors or malfunction of the system. The testing process is performed by writing test cases. The above Table 6.1 shows the test cases written for the project IOT based Smart Energy Meter. The test cases are written for a given input and the expected output is compared against the system produced output which is the actual output. If the expected output is same as actualoutput, then the corresponding test case is marked as Pass, else it is marked as fail. The failed test cases should be re-evaluated and the required corrections are to be made to fulfillthose cases. The project is considered as a success if all the anticipated test cases pass. Theadvantages of performing System Testing are:

1. The System Testing ensures verification of the technical, operational and the business requirements.

2. System Testing helps in identifying and resolving any existing defects, bugs, errors and malfunctions.

3. The System Testing is an important part of Software Development Life Cycle (SDLC) to perform end to end verification of the project.

4. Testing the system makes it possible to provide a well-functioning system for the use by the end users.

Chapter 7

RESULTS

Fig 7.1 Working model

Fig 7.1 shows the working in normal state of the SEM module.

The Oled screen displays the total energy being used on the board. The energy meter is active. Here the Output is feed to current sensor where it checks for any theft of current. Output of the current sensor is then feed to microprocessor. Here, if the Theft current is detected, it displays theft defected on the Oled and then proceeds to cut the supply to the load which in turn turns on/off the load depending on the scenario and stops.

If no theft current is detected, it displays the value on the Oled display and updates the cloud with the energy output which calculates the bill according to the amount of energy used and display the information on consumer mobile device. Simultaneously, on the other hand, driver is used to drive the load to turn on/off the load which then stops the process. Here, if the Theft current is detected , it displays theft defected on the Oled and then proceeds to cut the supply to the load which in turn turns on/off the load depending on the scenario and stops.

Fig 7.2 Energy consumed in units

Fig 7.2 shows the output of the SEM module on adafruit dashboard.

As we can see in the figure, when the electric bulb is switched On, the units of energy consumed in the graph rises linearly as there is power consumption detected thus the SEM module is able to detect the units of energy consumed and this data is sent to the cloud and updated on the devices which keeps us posted on the energy consumption.

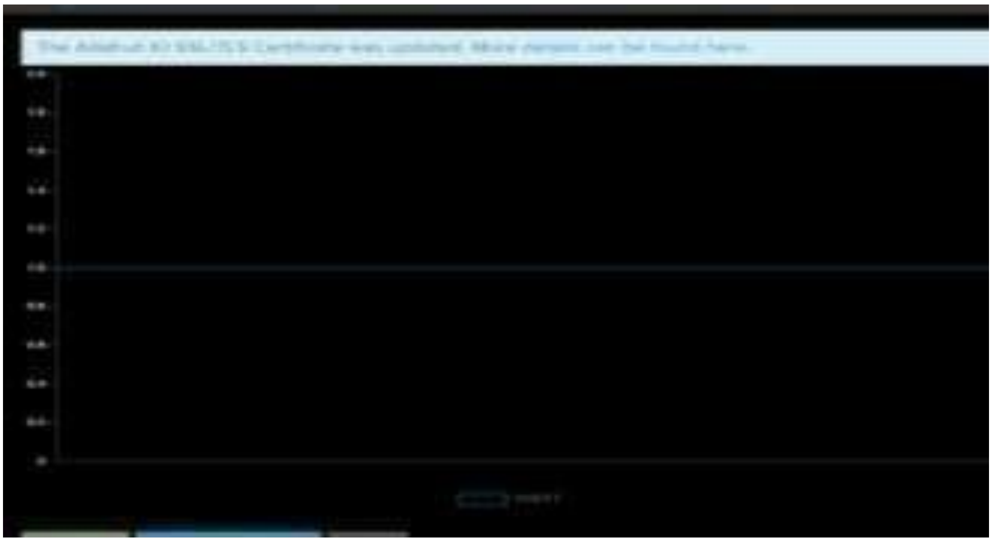


Fig 7.3 Theft mode power consumed.

Fig 7.3, we can observe, when the SEM module detects power theft, there is no rise in the units consumed graphs, as there is no supply of current or the SEM module cuts of the electric supply once power theft is detected.

Fig 7.4 Charted data of energy consumed in units

Fig 7.4 shows the charted data of the energy consumed in units, thus providing us the real time data of the energy used , keeping us updated with our power consumption. The intervals at which the consumer wants their updates can be set accordingly according to their convenience.

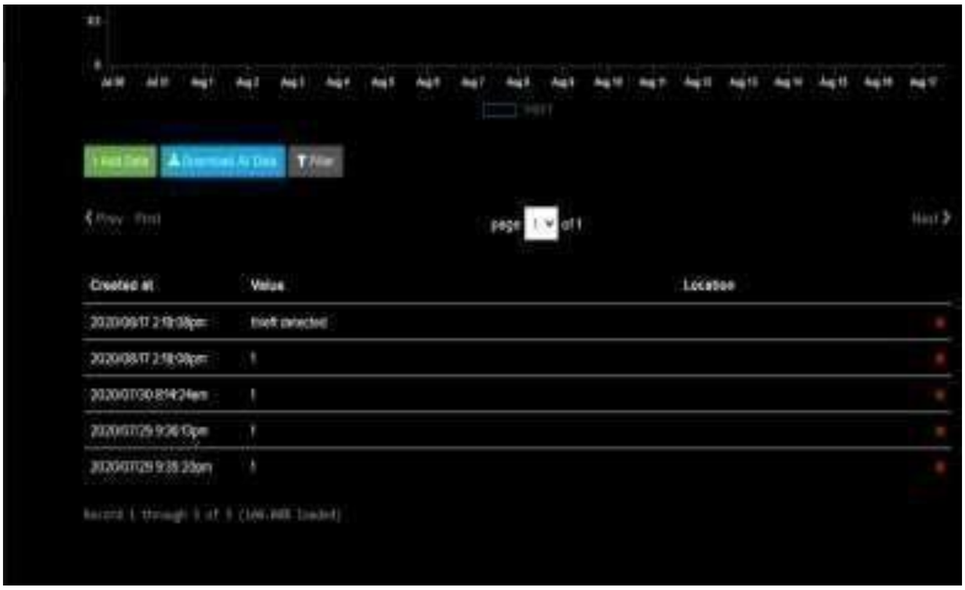


Fig 7.5 Charted data of theft detection occurred.

Fig 7.5 shows the charted data of theft detection occurred , thus there is no energy consumed as the SEM module cuts of the power supply preventing theft .

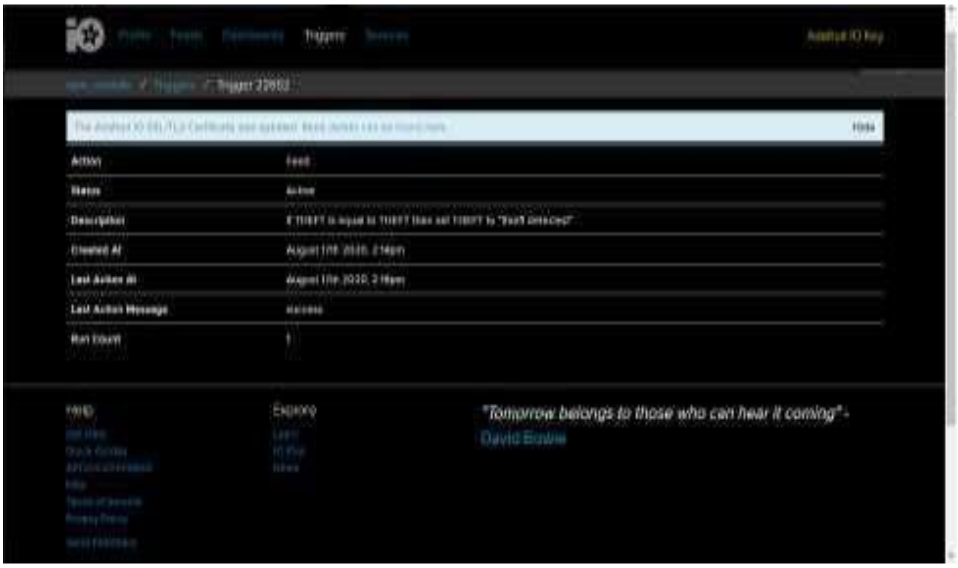


Fig 7.6 Configuration of theft data trigger.

Fig 7.6 shows the configuration of theft data trigger . here it shows aspects such as Action, Status, Description, created at last action and Run count thus providing with the complete information keeping the customer at complete transparency and control over the meter.

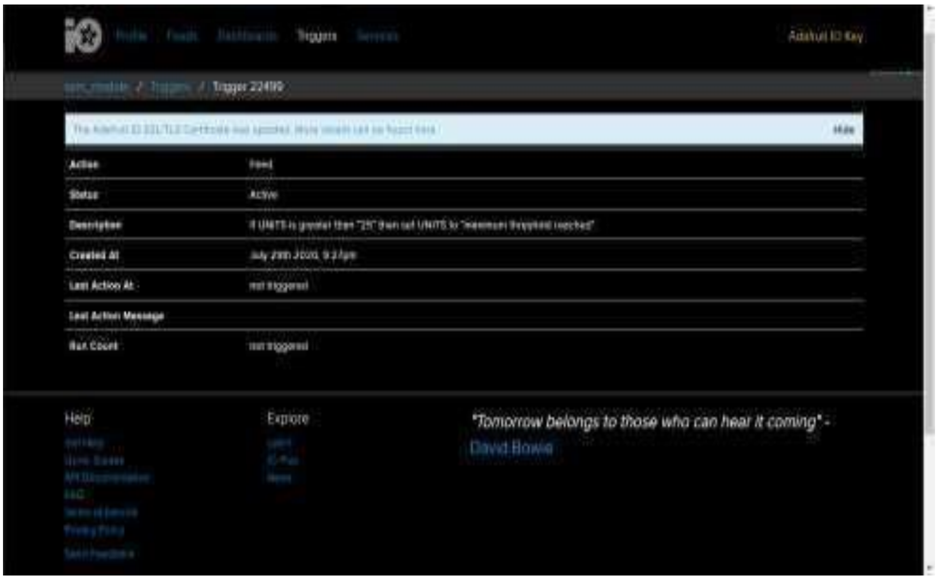


Fig 7.7 Configuration of threshold value trigger

Fig 7.7 above shows the configuration of theft data trigger where the aspects mentioned earlier are used to provide information, as in this example, where if units is greater than 25 units, then set units to maximum threshold reached.

SUMMARY

A smart meter is a digital meter that replaces old analog meters, which are used in homes to record electrical usage. These digital meters can transmit energy consumption information to the utility (as it is connected to the internet) in frequent intervals, and can monitor consumption more precisely, thereby enabling more informed energy choices. smart meters help in monitoring and managing electricity consumption and save money. It can be like your mobile pre-paid connection. Smart meters help power distribution companies to conduct power-quality analysis in near-real time, taking into consideration factors such as maximum demand, voltage fluctuation, outage detection etc. It helps reducepeak power purchase cost, thereby improve business efficiency. This in turn reduces their debt, thereby helping the economy. Smart meters also aids in the recovery of receivables, which has caused a huge stress on the system. So, it can help to plug leakages in the wholechain. The total amount of power consumed in an individual household is referred as power consumption. The consumption of power is an important aspect of electricity supply. People should be aware of preserving energy for future use. With daily usage of electricity, the energy patterns have been slowly varying. This variation of consumption patterns can be caused by weather conditions or unnecessary utilization of power by inhabitants such as increase of appliances in respective households and careless attitude in utilization for example not switching off the lights or television when not watching it. These factors may show greater impacts on end user.

CONCLUSION

Conversion of a present energy meter into a smart energy meter using our Smart Energy Meter module. The smart energy meter module measures the power and consumption. The device has the capability to monitor and communicate with our servers in the cloud to provide real-time information data on our power consumption details and cost to the consumer. This system allows the consumer to monitors and tracks their usage. Information about energy consumption helps user to reduce energy usage and their save both money and energy and we have interfaced Arduino with Energy meter (analogue) through an Optocoupler. This system provides the domestic power consumption accurately, safely, and with a relatively fast update rate, thus helping the user optimize and reduce their power usage and also provides wireless meter reading system that can monitor and analyze the data at every interval providing accurate results with less error.

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APPENDIX A

A.1 Arduino 1.6.12

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, Mac OS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards. The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main () into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program AVR GCC to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

Adafruit.io

According to its developers, "Adafruit is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. Adafruit enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates". Adafruit was originally launched by ioBridge in 2010 as a service in support of IoT applications. Adafruit has integrated support from the numerical computing software MATLAB from MathWorks, allowing Adafruit users to analyze and visualize uploaded data using Matlab without requiring the purchase of a Matlab license from MathWorks. Thing Speak has a close relationship with Math works, Inc. In fact, all of the Adafruit documentation is incorporated into the Mathworks' Matlab documentation site and even enabling registered Math works user accounts as valid login credentials on the Adafruit website. The result obtained will been uploaded to an open IoT platform "Adafruit which help us to store, collect, analyze data from Arduino and other supporting hardware. Adafruit documentation is incorporated into the Mathworks' Matlab documentation site andeven enabling registered Math works user accounts as valid login credentials on the Adafruit website.

A.2 Source Code

```
#include <Wire.h>

#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#include <ESP8266WiFi.h>

#include <DNSServer.h>          /* Local DNS Server used for redirecting all requests to the configuration portal */

#include <ESP8266WebServer.h>   /* Local WebServer used to serve the configuration portal */

#include  <WiFiManager.h>               /* https://github.com/tzapu/WiFiManager WiFi Configuration Magic */

#define VOLTAGE_DIVIDER     10.0f

#define REF_VOLT           0.9f

#define RESOLUTION         1024

#define WATTS_THRES        25.0

#define AC_VOLT            230.0

#define VPP_RMS            0.3535

#define BASE_PRICE         125

#define UNITS_UPL_FREQ      30          /* In 2Sec */

#define THEFT_THRESHOLD     15

#define VperAmp            0.1f         /* See AC712 Datasheet */

#define TRUE               1

#define FALSE              0

#define OLED_RESET         4

#define SSD1306_LCDHEIGHT   64
```

```
Adafruit_SSD1306 display(OLED_RESET);

const char* ssid      = "IotEM";              /* Device SSID */

String apiKey         = "GBH1K3293KFNO8WY";   /* Replace with your thingspeak API key */

const char* server    = "api.thingspeak.com";


/* Create an instance of the client */

WiFiClient client;

WiFiManager wifiManager;


/* Port Pin Definition */

int InVolPin      = A0;

int LoadPin       =  14;

int PulsePin      = 12;

struct {

  unsigned char LdCon: 1;

  unsigned char Units:1;

} Flags;

double Voltage, VRMS, AmpsRMS, Watts;

volatile byte interruptCounter = 0;

int Pulses = 0;

int PrevUnits = 0;

int PrevMUnits = 0;

int Units, MeasUnits;

#if (SSD1306_LCDHEIGHT != 64)
```

```
  #error("Height incorrect, please fix Adafruit_SSD1306.h!");
#endif
#define   LoadOn()   digitalWrite(LoadPin,   1)
#define   LoadOff()   digitalWrite(LoadPin,   0);
static void DispInfo (void);
static void DispStat      (void);
static void SendUnits     (void);
static void SendTheftInfo (void) ;
static void SendSMS       (int8_t Type);
static void DisplayUnits(void);
static void TheftOccurred (void);

ADC_MODE(ADC_TOUT);
void setup(void) {
  Wire.begin(0,2);
  Serial.begin(9600);
  pinMode(InVolPin, INPUT);
  pinMode(LoadPin, OUTPUT);
  pinMode(PulsePin, INPUT_PULLUP);
  attachInterrupt(digitalPinToInterrupt(PulsePin), handleInterrupt, FALLING);
  Flags.LdCon = FALSE;
  display.begin(SSD1306_SWITCHCAPVCC, 0x3c);
  display.display();
  delay(500);
  LoadOn();
```

```
  ConnectAP();
  DisplayUnits();
}
void loop() {
  static unsigned long i = 0, j = 0, l = 0;
  VRMS = getVPP() * VPP_RMS;
  AmpsRMS = VRMS / VperAmp;
  Watts = AmpsRMS * AC_VOLT;
  if (Watts >= WATTS_THRES)
       Flags.LdCon = TRUE;
    else
      Flags.LdCon = FALSE;
  #ifdef DEBUG
  Serial.print(Watts);
  Serial.print(AmpsRMS);
  Serial.println(" Amps RMS");
  #endif
 if (Flags.LdCon) {
   #ifdef DEBUG
      Serial.println(MeasUnits);
      Serial.println(Pulses);
      Serial.println(l);
   #endif
  if (MeasUnits == Pulses)
    if(++l > THEFT_THRESHOLD)  TheftOccurred();
```

```
 }
 if (i++ >= UNITS_UPL_FREQ) { /* End of Day */
   Units = Pulses - PrevUnits;
   PrevUnits = Pulses;
   SendUnits();
   i = 0;
  }
  if (interruptCounter > 0) {
     interruptCounter--;
     Pulses++;
     MeasUnits = Pulses;
     l = 0;
     #ifdef DEBUG
       Serial.print("Total Units: ");
       Serial.println(Pulses);
     #endif
     DisplayUnits();
  }
  delay(1000);
}
void handleInterrupt() {
  interruptCounter++;
}
static void TheftOccurred(void) {
  display.clearDisplay();
```

```
  display.setCursor(0,0);
  display.setTextSize(3);
  display.setTextColor(WHITE);
  display.print("!THEFT!");
  display.display();
  SendTheftInfo();
  delay(5000);
  LoadOff();
  display.clearDisplay();
  display.setCursor(0,0);
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.print(" Contact CESCOM");
  display.display();
  delay(2000);
  ESP.deepSleep(0, WAKE_RF_DEFAULT); /* RIP */
  for(;;);
}
void DisplayUnits(void) {
  display.clearDisplay();
  display.setCursor(0,0);
  display.setTextSize(3);
  display.setTextColor(WHITE);
  display.print(Pulses);
  display.setCursor(90,13);
```

```
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.print("Kwh");
  display.display();
}
void ConnectAP(void) {
  #ifdef DEBUG
    Serial.print("Connecting Wifi: ");
    Serial.println(ssid);
  #endif
  display.clearDisplay();                    /* For Display */
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(0,0);
  display.println("Connecting");
  display.display();
  wifiManager.autoConnect(ssid);
  #ifdef DEBUG
  Serial.println("");
    Serial.println("WiFi connected");
    Serial.println("IP address: ");
    IPAddress ip = WiFi.localIP();
    Serial.println(ip);
  #endif
  display.clearDisplay();
```

```
  display.setTextSize(2);

  display.setTextColor(WHITE);

  display.setCursor(0,0);

  display.println("Connected");

  display.display();

  delay(1000);

}

void SendTheftInfo(void) {

   if (client.connect(server,80)) {

    String postStr = apiKey;

           postStr +="&field2=";

           postStr += String(1);

           postStr += "\r\n\r\n";

     client.print("POST  /update  HTTP/1.1\n");

     client.print("Host: api.thingspeak.com\n");

     client.print("Connection: close\n");

     client.print("X-THINGSPEAKAPIKEY: "+apiKey+"\n");

     client.print("Content-Type: application/x-www-form-urlencoded\n");

     client.print("Content-Length: ");

     client.print(postStr.length());

     client.print("\n\n");

     client.print(postStr);

  }

 client.stop();

}
```

```
void SendUnits(void) {
  if (client.connect(server,80)) {
   String postStr = apiKey;
         postStr +="&field1=";
         postStr += String(Units);
         postStr += "\r\n\r\n";
    client.print("POST  /update  HTTP/1.1\n");
    client.print("Host: api.thingspeak.com\n");
    client.print("Connection: close\n");
    client.print("X-THINGSPEAKAPIKEY: "+apiKey+"\n");
    client.print("Content-Type: application/x-www-form-urlencoded\n");
    client.print("Content-Length: ");
    client.print(postStr.length());
    client.print("\n\n");
    client.print(postStr);
  }
 client.stop();
}
float getVPP() {
  float result;
  int readValue;             //value read from the sensor
  int maxValue = 0;          // store max value here
  int minValue = 1024;          // store min value here
  uint32_t start_time = millis();
   while((millis()-start_time) < 1000) //sample for 1 Sec
```

```
  {
     readValue = analogRead(InVolPin);
     // see if you have a new maxValue
     if (readValue > maxValue)
     {
        /record the maximum sensor value/
        maxValue = readValue;
     }
     if (readValue < minValue)
     {
        /record the minimum sensor value/
        minValue = readValue;
     }
  }
  // Subtract min from max
  result = (((maxValue - minValue) * REF_VOLT) / RESOLUTION) * VOLTAGE_DIVIDER ;
  return result;
}
```