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“Data Analysis: Energy Consumption in Smart Homes (IoT)”

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Abstract

This thesis introduces a digital microcontroller to calculate energy usage and its related billing scheme. Design details for energy meter construction (Current transformer, Potential transformer, microcontroller, Transmitter, Receiver, and a load). Electricity has become one of the essential needs of human society and is widely used for residential, manufacturing, and farming purposes. There is currently no special mention of the need and demand for electricity. Despite the very well developed electricity sources, both conventional and alternative models, the distribution, measuring, and charging of electrical energy and its calculation of consumption are complicated. The problem worsens when the meter readings are collected, and the bill is produced. In this paper, the approach used for using a wireless digital data transmission system was used to calculate energy consumption and its consequent billing system easily. If we use this energy meter, the power system will benefit. The process is very cost-effective and straightforward. This science depends on reasoning, rationality, and commitment. Our world is fascinated by the introduction of new technologies. This study discusses one method for carrying out the mission described above. It displays current, electricity usage, and maximum demand. This thesis provides more information on the UART (universal synchronous communication between receiver and transmitter) system for transmitting data to the PC.

Table of Contents

List of Figures

Listings

Acronyms

EMS	Energy Management System
ISO	International Organization for Standardization
MVP	Minimum Viable Products
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
SPI	Serial Peripheral Interface
PCB	Printed Circuit Board
ESP8266	Espressif Systems Microcontroller with Wi-Fi integrated
ESP32	Espressif Systems Microcontroller with Wi-Fi and Bluetooth integrated
CT	Current Transformers
AC	Alternating Current
DC	Direct Current
ADC	Analog to Digital Converter
RDBMS	Relational Database Management Systems
NoSQL	Not only SQL
OS	Operating Systems
IoT	Internet of Things
VPN	Virtual Private Network
JSON	Java Script Object Notation
BSON	Binary JSON
NodeMCU	Node Micro Controller Unit
COM	Communication Port

1. Introduction

Reduction in Active energy consumption is one of the main policy agendas for energy. A program “Energy 2020” was formed by European Commission with the purpose of lessening the consumption of energy until 2020 by 20%. To have an efficient usage of energy, we should use technology-based products which assists people in performing actions that can reduce its usage, without causing them discomfort. With the technology, the mindset should also change. People currently take energy as granted, and do not take actions towards not wasting it. When the energy provider fails, that period of time can make people think. Institutions consider energy costs as an over the head costs, and not all of them helps in saving energy. Potential advantages in economic and ecological area are mainly unknown. International Standard was invented for reducing energy consumption, International Organization for Standardization [Int47] formed ISO 50001 [ISO11] standard to provide a structure with best practices to establish, implement, maintain and improve Energy Management Systems (EMS) which provides a tool set that gives a summary of the energy’s usage status in a building. Knowing all of this, decreasing the consumption of energy and reducing cost of operations without disturbing people’s comfort is possible. EMS executes three main tasks: gathering the energy data, interpret it and then present users the results in shape of reports. To analyze further, use the energy meters to gather the energy data. When data is reported by just some energy meters, it acquires only a limited view of the building consumption. Larger the building is the lower the detail is obtained. Preferably, spreading hundreds in a large building, performing techniques of sub-metering which can lead us to a very brief detailed report which helps in reducing consumption of energy. With many low-cost energy meters, it is possible to correctly measure all the energy that is being spent in a building, with an adequate level of accuracy and a reduced cost. The more meters are used, the better the result will be. It is a better approach to the problem to use many meters, than just one, and the herein proposed solution uses several low-cost meters instead of an expensive one. It “divides to conquer" instead of using just one highly advanced and expensive meter. Although, the meters are of high costs which hinders a complete consumption report. Smart energy meters exist in the market in large number, but every one of them has a high price that makes it unreasonable to spread them in a large building to manage the costs of electricity. Such situation leads to bad reports not supporting the building manager to detect and then correct probable problems which results in waste of energy and the EMS is supposed to prevent it. The main purpose of this thesis is creating, documenting and validating a wireless energy meter of low-cost to report consumption of energy data to the EMS. With the cost of just some smart energy meters available in the market, a building can have such energy meters spread all over it.

Research Field

Home automation is gaining importance because of its various benefits. It is defined as controlling home electronic appliances and other domestic features through local networking or using the remote control. This is accomplished through artificial intelligence as it provides real-time decisions and automating the Internet of Things. Home automation is concerned with various intelligent home systems and technologies to form a different perspective. It works by monitoring and controlling operations of home or other electronic appliances through the use of smart devices that are mounted in residential buildings. Several number of home automation systems have been developed so far, which are based on central control, web, email, Bluetooth, mobile, ZigBee, Multi-Tone or Frequency, cloud, or the Internet giving the best performance. Automation is defined as a technique, procedure, or a well-operated system for operating or controlling through electronic devices that reduce human interference to the minimum. The need for developing such a system for office or home applications is rising day by day. This technology is being employed by the industries and researchers to develop an efficient and affordable automatic system that monitors and controls various machines, including lights, fans, Air conditioners, or other electronic equipment, according to the needs. Automation helps in making a system that uses electricity efficiently and economically. It also helps in the economical usage of water and minimizes wastage. Presently, Internet-based applications and appliances connect people anywhere and anytime through the use of any network or service. Automation is an important aspect of the Internet of Things. It helps monitor energy consumption and control the environment in buildings, educational institutions, offices, and more through the use of various sensors and actuators controlling lights, temperature, and humidity. This smart, innovative technology provides economic, social, and environmental benefits to a number of businesses. Among the others, one of the most important features that define its success is data analytics dealing with data acquisitions, data transmission, processing, and interpretation, bringing benefits to all businesses. In the emerging home IT marketplace, smart home systems are becoming significant. In these systems, major challenges encountered include security, efficient energy consumption, and comfort. To tackle these challenges, comprehensive systems have been developed that manage and operate these issues through a unified dashboard. The use of remote monitoring systems is very common in smart homes. These systems employ telecommunication and modern web technologies for providing automated remote control and support services from specialized help centers. Smart homes serve as a better alternative by providing automated appliance controls and other services. They enhance user convenience through context awareness and predefined constraints depending on the situations of the home environment.

Aim

The main aim is to raise awareness among population about their energy footprint. To achieve this, we consider that a device can be developed that will measure the electricity and provide this information to the user. This data should later be analyzed, summarized and visualized so the end user better understands them. Furthermore, the information should be provided in real-time. The target audience of this project will be the general population, or a typical household as well small businesses or other interested parties. Problem is represented by Meter pricing commissioning smart-meters. Although, in most cases, installation of smart meters in an existing building is a problem. If EMS is implemented in an old or historical building, passing communications cable can show a difficulty. In new buildings, spreading communication cable is not that much of a problem, that’s why it can still be involved in the project. A smart meter does not need to offer several complex functions to be effective. In fact, the simpler it is, the less it will cost. A simple meter with energy measurement and server reports as only tasks shows a great potential. With the information provided by the meter, the server can perform those complex functions and produce better reports. Besides of this advantage, the information will be reported not just by one meter but also by dozens of meters spread all over the building, having in the end a much better view of the energy spent. The key for a low-cost meter is to implement the simplest meter solution that only reports its measures to a central server. This solution will allow the development of simple energy meters, while the main intelligence of the system is provided by software in the central server. With this kind of solution, a complete system can be produced with a low price, and this document will further discuss and detail how to implement a low-cost meter. An advantage of having low-cost meters is the possibility of performing sub-metering in a room by using multiple energy meters, and therefore know how much each equipment is consuming, instead of having just one meter that costs the same as the sum of low-cost ones, but only is able to identify how much the room is consuming.

Besides many EMS solutions available in the market, to increase their adoption, we have to resolve their common problems:

Price of energy meters is too high so it's difficult to install them in a large building in huge number, but this difficulty does not allow them to perform sub-metering at a low price with a desirable resolution.

Installation cost is another important aspect that can further be classified into:

- Electrical installation of the energy meters should be performed by qualified personal giving us an avoidable cost if the process of installation is simple
- Another problem for client is that we also need to power down the buildings.
- In older buildings, Installation of Communication cable can be a problem, where addition of new cable may not be a trivial.
- Many interactions with specialized software are required by a commissioning effort which is required by each meter.

EMS solutions still contain these problems, and there is not a single solution that does not have the mentioned problems, however it is may be possible to resolve them by using open electronics hardware of low-cost that can be easily installed without having previous specialized information about the electricity and that also offers auto-commissioning. This is the main objective of this thesis, and this document will focus on the first main task of EMS, by presenting a low-cost solution for gathering energy data using open hardware, including details about current measurements and deliverance to the main server using a low-cost wireless network.

Hypothesis

- A system that will collect data from current sensors in a microcomputer can be implemented
- A web-based data analytics platform can be implemented that will present useful consumption metrics to end users

Research Methodology

Several approaches will be considered during this research. Therein, the project will be divided into three parts: a state-of-the-art study, a data gathering, experimental phase and a data analytics phase.

During the state-of-the-art study, we will conduct a literature review of similar research done by the scientific community. Results of such result will be gathered and compared in order to determine the viability of each approach and the most suitable method that we can use.

The second phase will be the experimental phase where we will gather data and implement a small-scale home automation system. Depending on the previous phase, we will consider using among platforms such as Arduino, Raspberry PI, Micro Python supported boards etc. The aim is to implement MVP solution (Minimum Viable Products), one of which will be limited to data gathering for a single sensor (home appliance).

Finally, to utilize the data gained from sensors that we have the data in our usage we will conduct a quantitative analysis. During the analysis part we will collect all the data from the device sent to the database and visualized in the web app in a chart. Measurements will be displayed in the chart for how much usage is performed for the whole day and some other features will be added for billing and having reminders of usage of the power. So, the visualized part should be in a various way so the collected data to be analyzed by every user in an easy way and to be more suitable for understanding the consumption. The data will be in KW/H displayed in the chart in a real time, and billing in denars.

2. Literature Review

Historically, household electricity data which reveals no inside information of behavior of electricity usage, is solely accessible from the approximated or in some cases actual three-monthly combined value. Many of the studies had been conducted to conclude the actual values of the requirements of the energy from the other sources like the size of the house, type of the house, etc. and the socio-demographics. Indeed (Nezhad) is saying that Smart D is a system that has the ability to make a picture of energy usage of clusters of consumers, a set of individual consumers, or both in which the use of a common grammar id which is also very flexible, will be used to determine the wanted picture is proposed. Here, the id will identify the user, clusters are separated by the character ";", and consumers within a cluster are separated by the character ",". In this method, any individual user of the energy will be shown as a group of one user. And if a cluster is of greater than one user is stated, the consumers can decide the roles to combine the values obtained of the energy consumption inside the group (for example average, total, maximum, or minimum). In his work, the author has also displayed a dashboard for data analysis of smart meter and the picture formed of the GSN. SmartD is out as an open-foundation scheme with abilities including picturing of the data related to power usage and the approximation of consumer's power load conferring from the contextual and the demographical data. In coming time, some additional functionalities like the user breakdown, missing values determination, and load forecasting can be added.

New projects are being presented to the world like the management of the consumers, and the demand feedback system which can accurately depict the power usage of the consumers. These are supposed to improve profitability and reduce cost, other best ways are being constantly searched for, by the utility companies, however, the result till now is not so good but sustainable results are yet to be achieved. The difficulty is that it's a challenge to understand individual habits of consumers and tailor the strategies that takes its benefits into account vs. the discomfort that's being caused because of the changing attitude of the people to the recommended power saving. This paper's aim to offer models for predicting, visualizing and analyzing power consumption statistics to expose patterns of several time-based power usage, which can proportionally reflect the expected comfort and behavior of consumers. The thesis also analyzes patterns of users' time-based power utilization at the level of appliance to guess the patterns of long- and short-term power consumption. The results obtained describe its consumption according to its connection with time in a domestic place that are main influences to study the effect of attitude of the consumer on usage of energy and, guess the patterns of electrical devices use while helping in power saving projects by making them successful and by using diverse methods said by (Shailendra Singh, 2018).

Datasets are becoming more relevant when measuring smart grid' algorithms accuracy and observing how good they may work in an environmental situation. In this field of research, the test of accuracy performance with datasets of real world is crucial. Realistically, actual dataset isn't represented by synthesized data as "a dataset of real world would have almost unpredictable certain complexity that can be very difficult to deal with". For smart grid's research, it's appreciable to have public datasets that shows how aggregate power readings are reported by smart meters with that accompanying sub-meter data for the diverse loads that comprises the aggregate power reading. In addition to NILM and smart grid, the information used in a research looks at statistical signal processing, separation of blind source, behavior in which energy is used, eco-visualizations, eco-feedback, verification and application of theoretical models/algorithms, studies of appliance, demand forecasting, frameworks of smart home, analysis of grid distribution, analysis of time-series data, studies of energy-efficiency, detection of occupancy, socio-economic frameworks, energy policy, and analytics of advanced metering infrastructure (AMI). The dataset contains more than 11 million power readings for an In-home display according to the project done by (Stephen Makonin, 2018).

Smart Energy is important in future use of energy because of the energy resources that are limited, nonrenewable and available on Earth and also obtaining renewable energies (REs) is very expensive, making effective and efficient usage of energy is critical for developments in future economic and social field. Key enabler for smart energy are smart grids (SGs), which mentions power networks which can integrate actions and behaviors of all the shareholders connecting to it, for example, customers, electric generators and those doing both—to proficiently provide secure, financial, and sustainable electricity supply.

“Smart meter” refers to the ability to measure the total utilized or produced electricity and the capability to regulate the source and cutoff as required. AMR’s one-way communication is used and AMR is capable for detecting tamper, automated monthly reads, and collecting usage data. The capabilities of AMR were modified with time. It could collect the information at shorter intervals, read the data on demand, and connecting into the system and collecting other statistics. An important advancement (incorporation of time-based rates, measure of quality of power, remote programming, service switching, and a control panel type user interface for monitoring AMR) happened after meters integrate with a two-way connection feature which is known as advanced metering integrated (AMI). According to (Damminda Alahakoon, FEBRUARY 2016), data analytics of electricity smart meter and smart metering is observed in a comprehensive survey. Also, we present in the paper the current smart-meter model, i.e. smart-metering space as the smart-metering landscape. Also, an outline for stakeholders has been made to compare the statistics and the uses of smart meter formed by the analytics tools, their needs and the methods needed to accomplish the stakeholder’s needs.

Without many efficient policies and programs, the use of electricity remains to increase. In Europe, twenty-five of the affiliated countries has the occupancy rate increased by 10.8% during the period 1999-2004. The annual power and energy consumption have tripled in the USA during the last 2 decades. Commercial and residential buildings contribute a large proportion of consumption of total energy, in the USA, 41% and in EU-25, 54%. In addition, energy consumption, estimated 30% is wasted. The Main Sensor will be able to look not only at the integrated load but also its components, e.g. The use of a specific fuse-group of circuit board power, to obtain the appropriate power consumption information. The main sensor should be connected to the kilowatt hour meter and to the distribution panel. Data is transmitted by telephone to avoid unnecessary cords. This tutorials’ purpose was to design and implement a new Main sensor on the UBI-AMI system 2 system that would give you a more complete view of your home power consumption than the UBI-AMI version of the Main Sensor

1. The sensor was made to measure the combined load of kilowatt-hour meter test output using galvanic or optical input says (Ylioja, 2014).

To improve the metering systems accuracy and efficiency, for a long time, the Automatic Meter Reading (AMR) model has been used and discussed. It is the technology for collecting data automatically from metering energy devices (electricity, gas and water) as well as transferring data to central payment databases and / or analytics. This states that instead of previous usage, billing can be based on actual consumption, giving consumers better control over their energy consumption, gas consumption, or water consumption. ESP32 technology is less energy usage, less data amount and still less wireless communication protocol. ESP32's application profile includes home automation, automatic meter readings, home and hospital care, wireless sensor networks, and more. Through the coordinate node, communication can happen between the end device locations and another location. A network of collected trees is basically a network of many stars arranged by a coordinator which is responsible for selecting specific network parameters and starting a network. Contact data locations communicates with the router and also connects across the router mode. Though, the router nodes performing the connection job are not able to communicate nonstop with another node, but with the router. Highly reliable networks were provided by the mesh network. A new wireless technology known as ESP32 technology, widely used for a variety of applications due to its high, reliability, efficiency, cost, and flexibility. In this thesis, the author has developed and implemented a new wireless communication network along with the protocol of smart electricity meter usages. According to (Somchai Thepphaeng, 2011) the result tells that the system can automatically read terminal alarm, the unit, and energy meter cover alarm and can use the operating systems.

Many applications can be supported if development of IoT technologies occurs. For example, transportation, intelligent power grid, medicine, healthcare, art, logistics, environmental monitoring, smart life, etc. If we see a smart home context, the wireless communications must be used by smart room objects because of keeping neat space for living and the necessities of helping mobile applications. Lately, many wireless technologies are designed and integrated for many reasons, although, most smart home applications disregard a wireless technology ESP32 which well-designed and also, an effective short-range technology for deployment scalability and power consumption. It is a wireless transmission protocol of low power, giving a data rate suitable for purposes of monitoring and controlling. In 1998, Honeywell Corporation formed ESP32 Alliance whose foremost mission is using low power wireless network protocols of IEEE 802.15.4, to develop IoT applications' specification. Although, communication occurs between mostly all of the developed devices and the ESP32 module embedded devices. (Chih-Yung Chang, December 2015) This research advises the integration of Wi-Fi connection, ESP32 communication, and broadband connectivity on a classic Wi-Fi AP, if we combine the AP with ESP32 normal connection. Through the advised method, an IoT AP can be obtained by an upgrade from the Wi-Fi AP.

Standard devices should be able to detect their surroundings and have some level of digital signal processing power and basic communication capabilities such as reading and writing comprehension information but limited to specific data-access devices. Smart devices are based on standard, yet powerful computer programmable devices, a measure to increase storage capacity and capability to access network. It is possible that smart devices communicate with each other. According to the access requesters, there is no significant difference in behavioral patterns between traditional Internet applications and the IoT. Thus traditional security technologies can continue to operate, such as, certificate and password based authentication, role-based access control models, and other general authentication. In this thesis, he says (Song, May 2013) first, the IoT and internet are compared. Although IoT is Internet-based, due to IoT features, such mature endpoint protocols and security measures (such as IPsec and SSL / TLS) on the Internet cannot directly provide a complete information safety through a transparent, application and the transport layer.

In EU, schools consist of 17% of the non-housing structures (in m2), while the wholesale/retail consists of 28%, and the workplaces 23% of the non-housing structures. Proof is available that emphasis of power usage in learning places for children lead to several advantages with provision healthy learning environment and educational excellence. This makes the schools as a perfect contender for using IoT technology. Moreover, this has various interesting and unique characteristics; firstly, schools and establishments (e.g., agencies) controls a lot of building structures. Also, one more aspect related to school's energy efficiency that makes it interesting is the fact that in past decades, expenses of energy in schools are treated as inevitable and relatively fixed. About (Dimitrios Amaxilatis, October 2017) a holistic approach is adopted to design an effective system with a vision that's sustainable, using IoT infrastructures joined with interface mechanisms and various set of feedback, so in long term time, it can make its end-users to change behaviors. The system is arranged in schools of several countries. In real world, displayed performance evaluation is evaluated comprising of 13 schools, and complete analysis explains its versatility, scalability, and responsiveness in completing needs of different applications. The results tell us that the highly effective system deals with the individual construction information about the power load, nearly in actual time by means of responses and properties of a typical server, with an application of less than 2 second response time. The system that's showed offers a rich set of APIs to use positioned sensing devices information along with the information poised in actual time. The building managers are targeted because of the presentation of many different applications (e.g., the BMS appliances), appliances that increase the in-door school activities and applications of mobile that engages students in various activities extending also to outside school hours.

The availability of actual time information on power usage gives us the multiple ways to decrease the power usage. It is done by making us able and bettering the already present techniques for using energy efficiently and managing its production. The concentration of this research is on comprehending the advantages that will be obtained after applying the collected data of power usage onto the management of power production. Also, to find the methods to determine the ways to increase the abilities of the power production management. The accessibility to the power usage data pattern in actual time is very important to find the ways to save the power, for example continuous maintenance, balancing of load, etc. This immense requirement of power usage awareness resulted in obtaining the interest of numerous corporations to give unique and efficient ways to monitor and control the power consumption for the industries (e.g. EpiSensor, Wi-Lem, ReMake Electric, Schneider, SATEC, Energy Metering Technology Ltd., etc.). In the same way, many corporations came forward to give Enterprise Energy Management (EEM) software applications to analyze the information collection (e.g. Resource Kraft, and Google). According to (Fadi Shrouf, 2015) this study discusses an important topic which would be very helpful for those managements that need to enhance their power consumption efficiency in their factories and workshops. This topic will help them in reaching their goals. This results in enhanced awareness, which is applied very flexibly and is able to gather power consumption related data in very massive amounts, that too in actual time. This is the cause of significance to timely develop the IoT power consumption monitor systems which have to be incorporated in the power management approaches of the company.

3. Design of Hardware

Design of a hardware, no doubt, as compared to software is more constrained in the physical world. Examining the abstractions that have worked for hardware is instructive, for example synchronous design. Hardware uses synchronous abstraction broadly to build complex, large, and modular designs, and has just been applied to software, mainly to design embedded software.

3.1 ESP32

ESP32 is a solitary 2.4 GHz Wi-Fi and Bluetooth combination chip produced with TSMC extra energy saving 40 nm technology as shown in Figure 1. The design is specially built to attain the perfect energy, versatility, robustness, and reliability in a broad range of uses and various energy consumption profiles. With around 20 external components, for Wi-Fi + Bluetooth applications, ESP32 is an extremely cohesive answer of IoT industry. ESP32 integrates the power amplifier, antenna switch, filters, low amplitude sound gets amplified, and electricity administration elements. Entire answer to the issue needs minimum Printed Circuit Board (PCB) space. ESP32's unified circuit needs just twenty resistors, inductors, and capacitors, single crystal and single SPI flash memory chip. ESP32 unifies all the transmitting/receiving RF abilities consisting of switches of antenna, filters, electric amplifier, power management module, and circuits of advanced caliber.

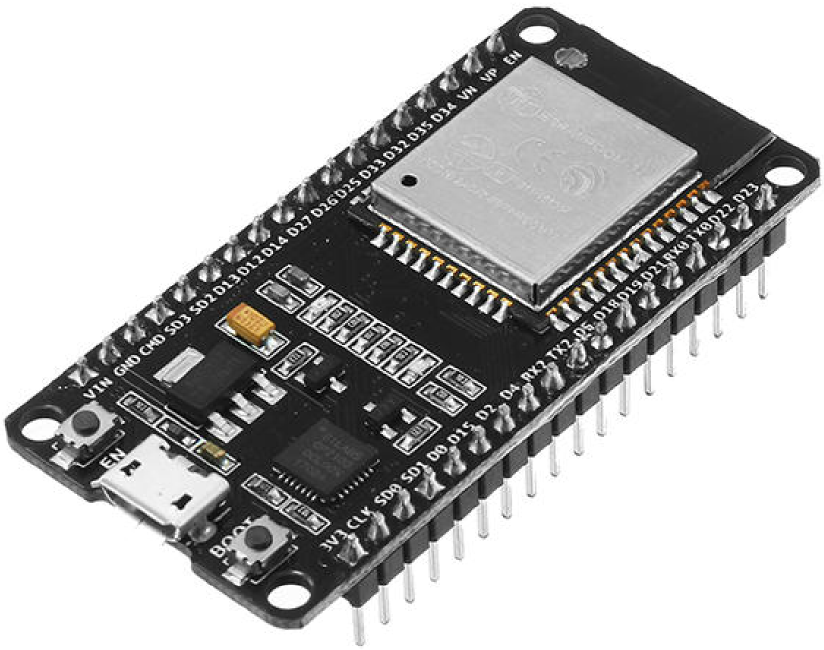

Figure 1 ESP32 Board

3.1.1 NodeMCU ESP8266

Espressif Systems designed a microcontroller named The ESP8266 which is a self-sufficient Wi-Fi communication service that bridges Wi-Fi from current micro controller and has the capability to run self-controlled usages. USB connector is built in, in this module. Similar to the functioning of Arduino, NodeMCU devkit can be connected to our laptops and can be flashed without any problems using a micro USB wire.

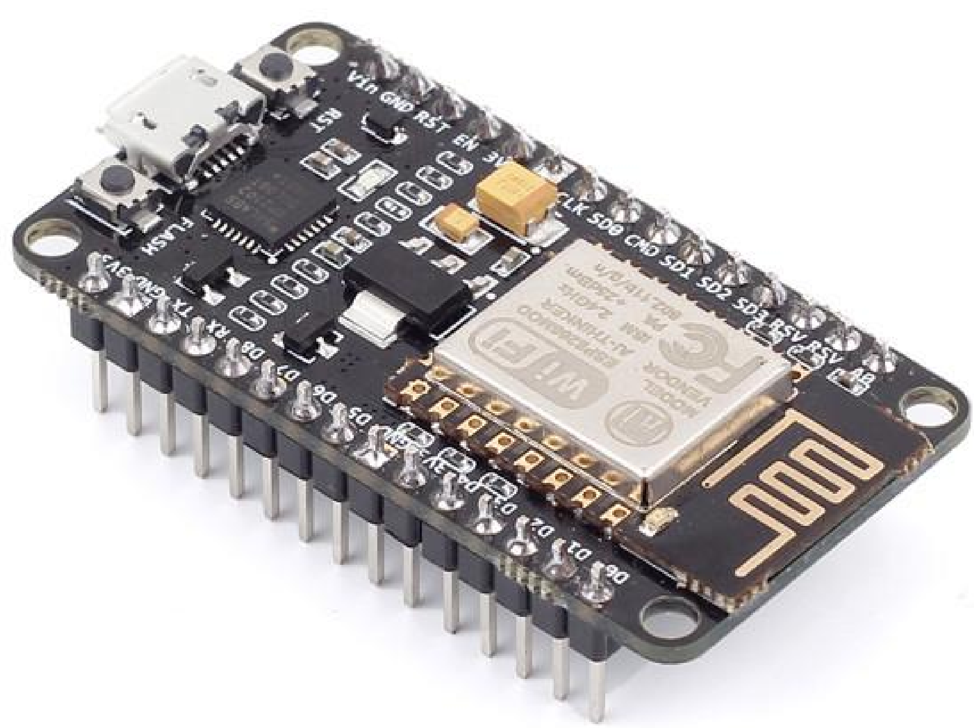

Figure 2 NodeMCU 8266

3.2 AC Current Sensor

The SCT013 line of production are current sensing devices and convertors that calculate current's intensity without being invasive, with which a conductor is crossed without cutting or altering the conductor itself. These sensors can be used with an Arduino like processor, to measure the consumption of power by intensity or a load.

These sensors are instrumentation devices which gives a measurement that's crossed by the circuit and which is proportional to the intensity, also they are current transformers. Electromagnetic induction measures it.

SCT013 sensors like a clamp, has a split core that permits user to wrap electrical equipment without cutting it off.

Models provide measurement as a voltage or current output. Simple and easy connection is the reason that voltage output is advised to be used.

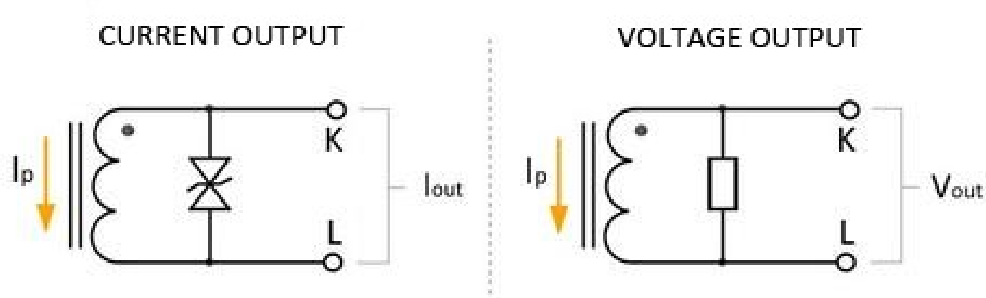

Figure 3

Output of Current Output of Voltage

Sensor's accuracy can be off by 1-2%. Highest accuracy is ensured by confirming that the core has been closed properly. 10% deviation can be caused by a small air gap. Being an inductive load, there is a disadvantage that the SCT013 introduces phase angle variations, whose value is the load' function passing through it, meaning that this is capable to reach up to 3º. In the world of industry, current transformers are common components whereas in power supply, they permit the monitoring of usage points, while other measurement forms do not exist. They are also known as instruments for multiple measurement. In home automation projects and our electronics, SCT013 current sensors are used for measuring the device electrical consumption, for checking electrical installation status, and to record electricity consumption in energy monitors of home.

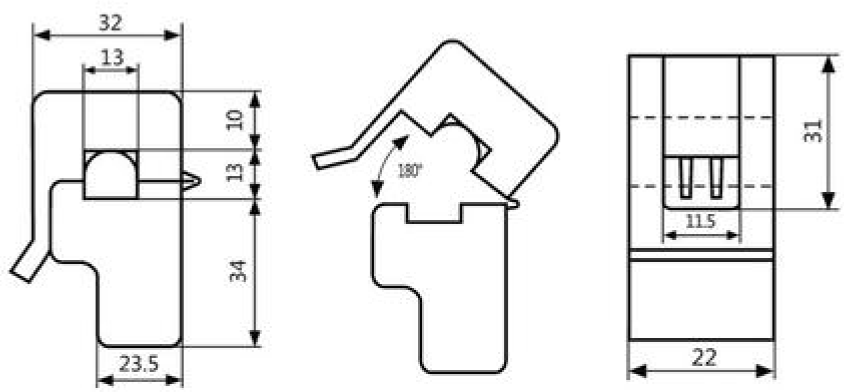

Figure 4 Sensor Overview

SCT013 series have range of models which can alter range of measurement and shape of output. They are physically same but can be identified by the written text on shell of the product.

Figure 5 Sensor Picture

SCT013-000 is most common model with the current of 100A maximum, 50mA (100A:50mA) is current output, 30A (30A/1V) is SCT-013-030 maximum current and 1V is the voltage output.

Now, even though it's compulsory to have measurements of broad range, it is also compulsory to accept that less precision will be resulted from a higher intensity model. 30A to 230V intensity corresponds to 6,900W load, that is more than sufficient for majority domestic consumers.

What is the mode of function of SCT013?

Small electricity converters are the tools utilized broadly for calculating the essentials.

A voltage converter is same as the current transformer and is made on similar and previously identical operating principles. Although, due to being differently constructed and designed, they have different objectives.

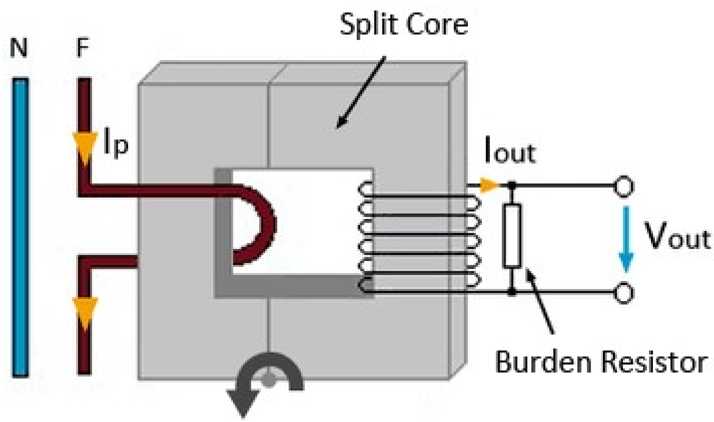

Figure 6 Current Sensor Breakout Diagram

An intensity in the secondary is generated by a current transformer which is directly related to the electric intensity which is passing from the main. Because of that, reduced number of turns forms primary.

Current transformer can be used to build current sensors that are non-intrusive. In the current sensor, to open and roll up the conductor separate the ferromagnetic core.

So, in a transformer,

- Primary Winding is the wire from which the flowing electricity is calculated.
- The "clamp" is the magnetic core.
- The part of the probe is integrated by secondary winding.

In the ferromagnetic core, magnetic flux is generated when the conductor has alternating current circulating through it, which causes electricity generation in the other winding.

The intensity conversion fraction rest on the association with the total amount of windings:

$$\frac{Ir}{Ip} = \frac{Vp}{Vs} = \frac{Np}{Ns}$$

A conductor makes a single loop which normally forms primary to be measured. Also, it is probable to make this happen inside the "clamp" more than once by winding the driver. According to SCT013 models, number of turns of the secondary, varies from 1000-2000, integrated in the probe.

In a current transformer, you should never open the secondary circuit as the component can be damaged by induced currents. Due to this, the SCT13 sensors have protections: resistance burden or protection diodes in the sensors.

3.3 Reading AC Current Data

In this field of the thesis we must explain about the components used and their functionality how the components and microcontroller are connected with each other. So, in this project we have used a microcontroller Node MCU ESP8266, AC Current Sensor that measures the intensity of the electricity, resistor, capacitor, breadboard, and some jumper wires.

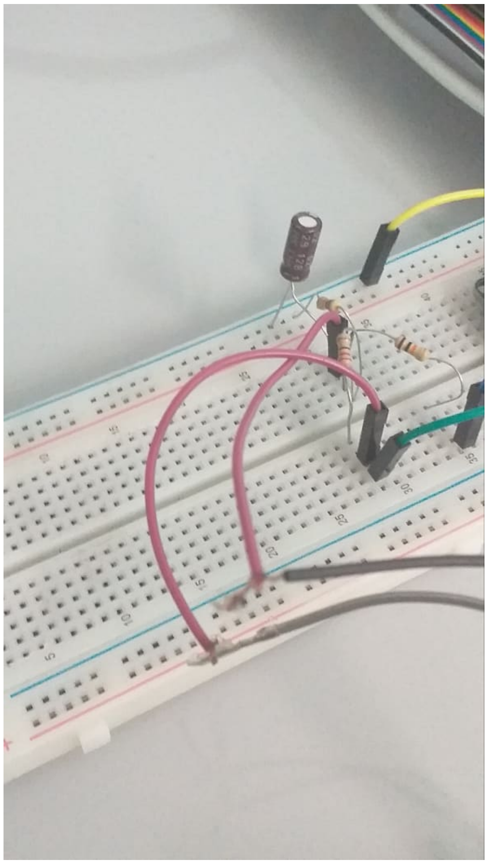

Figure 7 Picture taken of breadboard and components on it

In a microcontroller there is just one analog input (ADC) so we are connecting one side of the jumper wire to the A0 (ADC) pin and the other side in to the breadboard where A0 pin meets one side of the 10kOhm resistor and capacitor, the 3v3 wire meets the 18 ohm resistor and the 3rd and the last wire is the Ground (GND) wire which meets the other side of the capacitor.

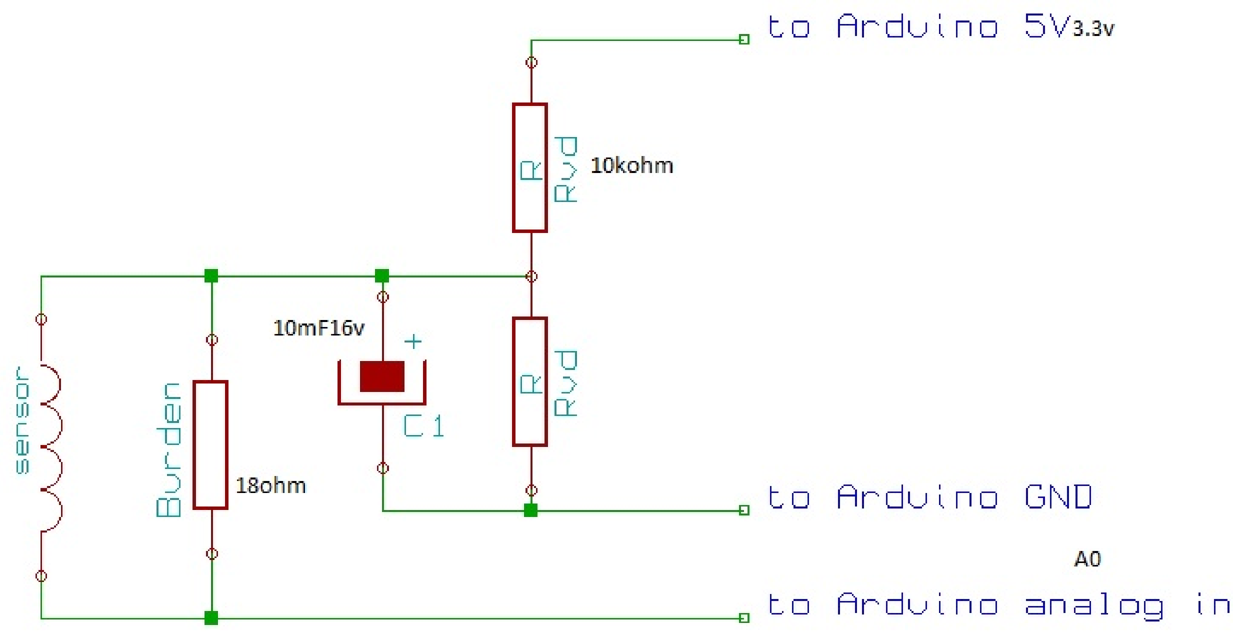

Figure 8 A schema that explains the connection of wires on breadboard to microcontroller

Indeed, the sensor has two wires that has to be connected in the breadboard so one of the wires are connected in the burden, capacitor and to resistors connecting with microcontroller's 3.3v pin. In the other side the other wire of sensor is connected in the A0 where the sensor wire meets the 18ohm resistor in microcontroller. After all these connections that we have done in our breadboard we have to connect the microcontroller with the micro USB cable to the PC (laptop/computer) to have connection for data transfers. Instantaneous values of current are being received from ADC. The sensor must be calibrated so we will calibrate within the Arduino in the code part. The results will be accumulated to produce the final result from microcontroller. The values are stored and are sent to server to be calculated.

3.3.1 Power factor

The Power factor indicates how efficient an equipment is. This concept is important to understand the apparent power, explained next. The Power factor is a value that varies between 0 and 1. An equipment having a power factor of 1 means that all the energy used is actually converted in work, and not wasted by heat dissipation in the system. Equipment's usually have a power factor close to 1, which is the reason why 1 kWh is approximate to 1 kVA. With a power factor of 1, all energy consumed (apparent power) produces work (true power or real power), and in this case the kVA equals kWh. This is the case of resistive electrical loads, as mentioned before, in which the current and voltage waves are perfectly aligned in phase, thus not producing reactive power and resulting in a power factor of 1. Examples of resistive electrical loads are incandescent light bulbs, electric water heaters, and electric stoves. Other types of devices consisting of reactive loads, such as fridges and computers, and many others with inductive or capacitive components, such as coils and capacitors, may have a power factor closer to 1. In these devices, it is desirable to thoroughly chose the components, in order to minimize the reactive power in the circuit, thus achieving a better power factor. The higher the power factor, the less will be consumed by the device while producing the same work.

3.3.2 Apparent power

The apparent power is total energy consumed by a device to produce work. As mentioned before, it has an inverse relation: the higher the power factor is, the lower the apparent power. The right vertex is the Reactive Power measured in VAR. On the top: The Apparent Power is calculated in VA. The angle _ represents the Power Factor which affects the consumption of the system directly. A Power factor of 1 means 0, and the lesser the Power factor value is, the greater the angle will be. The total consumption of a device depends on its power factor. A smaller power factor means that the device wastes more energy in the network grid e.g., by heat dissipation in the lines, thus consuming more apparent power in order to produce the same work (real power). This is important, since electric providers do not charge in kWh (real power), but rather in kVA (apparent power). The total consumption (apparent power) of a device regarding its power factor, can be obtained with the expression:

$$AP = RP = PF$$

The apparent power (AP), measured in VA (Volt-ampere), can be obtained with a division of the real power (RP) calculated in Watt-hour by the power factor (PF). As a practical example, consider a 500 W computer power source with a 0.9 power factor. If the power factor were 1, then this equipment would consume 0.5 kWh, but with a power factor of 0.9, it will actually consume 555.55 VA (500 W/h / 0.9). The extra 55.55 W is wasted in heat form in the circuit or in the power lines, and it will be charged by the power provider, since, as explained before, they charge the apparent power (in kVA). The herein detailed concepts were the most relevant to understand how energy is measured and charged, thus providing the needed basis to understand how an electricity meter works and how it can be used to our advantage, to reduce energy waste, and consequently, energy costs.

3.3.3 Root Mean Square (rms) Measurement

It is a fundamental measurement of an AC signal's magnitude. Its definition is both mathematical and practical. Practically defined, an AC signal with the RMS value is the amount of DC needed to produce heat of equivalent amount in the same load. For example, a 1-amp rms AC current will heat a resistor to the same temperature as a 1-amp DC current.

$$Irms = \sqrt{avgI^2}$$

The RMS measures 'heating' potential of a signal. The Smart power meter measures RMS of current and voltage signals. RMS measurement of continuous signal is as follows

$$VRMS = \sqrt{1Tm \int v^2}$$

$$Irms = \sqrt{1Tm} \int i^2\, Tm0(t)dt$$

Instant values of voltage v(t) and current i(t). Tm presents the length of a single period of the measured analog signal.

RMS measurement of discrete signal is as follows

$$\mathrm{VRMS} = \sqrt{\frac{1}{\mathrm{N}} \sum_{\mathrm{n}} \mathrm{v}^2(\mathrm{n})}$$

$$\mathrm{IRMS} = \sqrt{\frac{1}{\mathrm{N}} \sum_{\mathrm{n}} \mathrm{i}^2(\mathrm{n})}$$

(n) and (n) are the corresponding discrete values of current and voltage. Samples number in a single period of the discrete signal is presented by N. The I and V signals sampling frequency is an integral multiple of the fundamental component (60 Hz) to ignore any aliasing chance.

3.3.4 Real Power Measurement

The real power measurement is denoted by the word P (power), it is calculated in Watts and is calculated as follows:

$$\mathrm{P} = \mathrm{V} \times \mathrm{I}$$

Sensor's real time measurements are received and then multiplied to estimate real time values of Voltage and current. Real time values are collected for fundamental component's single cycle. The resulting value is multiplied by 1/N, where in a cycle, the number of samples is presented by N.

Algorithm for real power calculation. Firstly, I and V instantaneous values are obtained and then multiplied later to calculate values of instantaneous power which are accumulated for the fundamental component's single cycle. The resulting value is multiplied by 1/N where number of samples in a single cycle is presented by N.

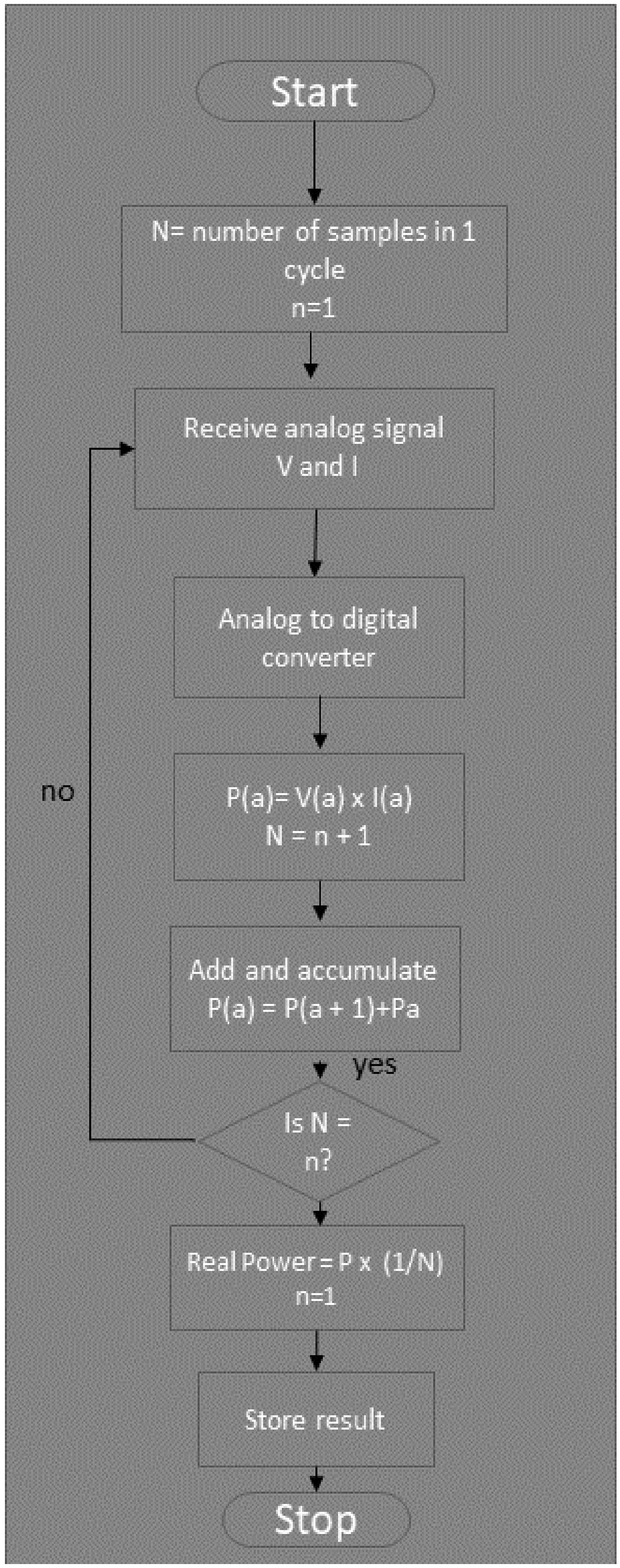

Figure 9 Algorithm for Real Power Calculation

The code responsible for this algorithm is following in listing 1:

```
double Irms = emon1.calcIrms(1480);

  Irms = Irms - 0.10; // Amperes calibration
  Serial.print("Current : "); // Printing as Current the value
  Serial.print(Irms); // Irms
  Serial.println("A");
  delay(500); // Printing the results in every 0.5sec

  Serial.print("Watt : ");
  Serial.print(Irms * 230); // Irms
  Serial.println("W");
```

Listing 1 - Power measurement code sample

The rolling out of AMI makes it possible to acquire near real-time information of energy use. There are several levels of real-time responses. One level is at the actual control of machines and equipment which requires milliseconds response time.

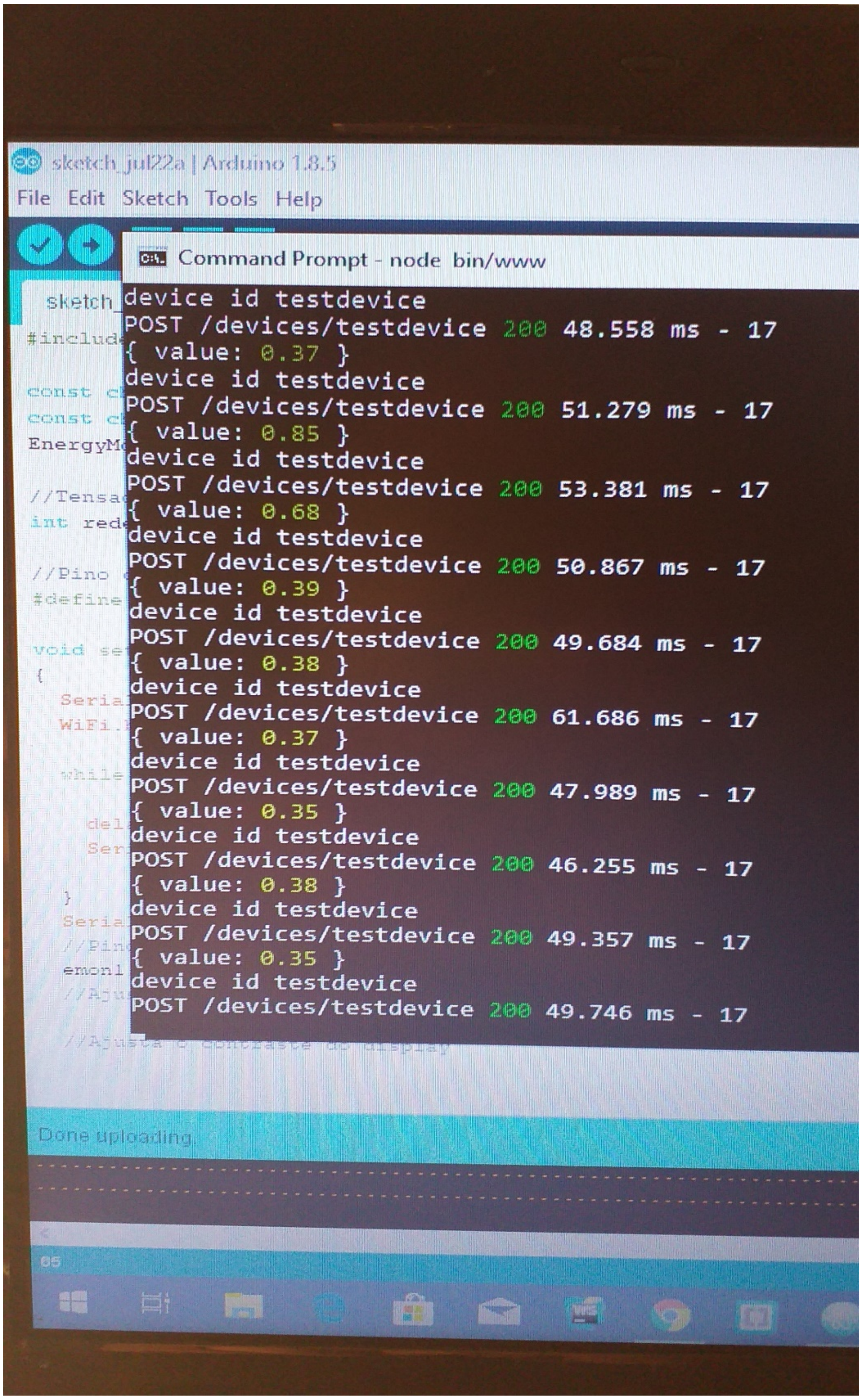

Figure 10 Picture of CT sensor readings in realtime

3.3.5 Reactive Power Measurement

The magnitude of the reactive power (S) is calculated as follows:

$$S=VIsin\theta$$

The Reactive power is measured in volt-amperes and it's calculated by implementing a time delay between voltage and current signals. This is based on the assumption that implementing a phase shift of $\pi 4$ in either v or i and multiplying it produces the same result as in equation 8. This method is accurate only if signals v and i contain only the fundamental component (60 Hz). The phase shift is implemented by shifting the voltage signal by a quarter cycle.

$$\mathrm{S} = 1\mathrm{T}\int (\mathrm{t}) \times \mathrm{i}(\mathrm{t} + \mathrm{T4T0})\mathrm{dt}$$

The reactive power algorithm is implemented by delaying voltage signals by a pre-defined number of samples equal to quarter sequence of the central constituent (60 Hz) of the signal of current. If the data is sampled at 3600 Hz and the fundamental component (60 Hz), then one cycle contains 60 samples. Hence, a quarter cycle of the fundamental component contains 15 samples. In the implementation, a data array is used to store 15 samples of voltage signals. The current samples are sequentially multiplied by stored voltage samples, buffered, and then sent to the server.

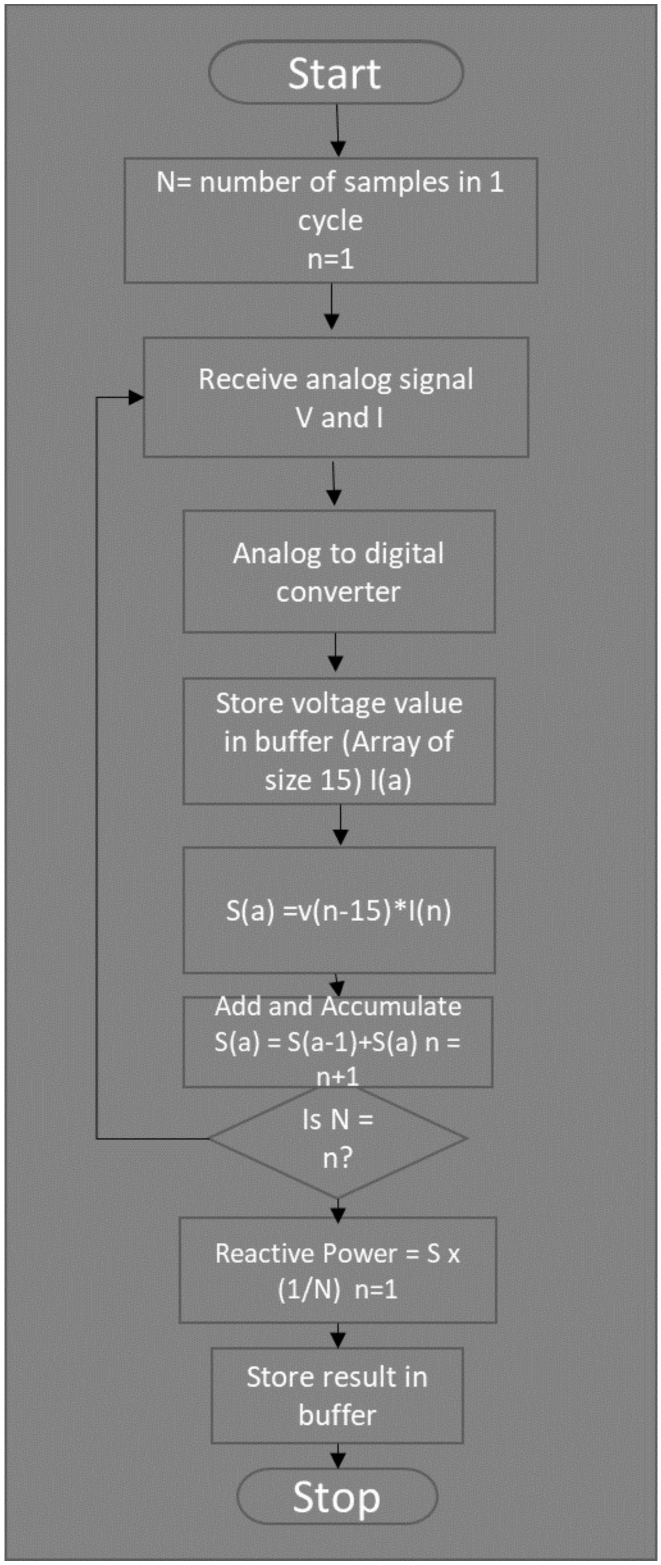

Figure 11 Reactive power measurement Algorithm

In the first step, voltage and current instantaneous values are received. The voltage value is multiplied by a delayed current value. The current value is delayed by fundamental component's quarter cycle. Power values are collected for fundamental component's single cycle. The resulting value is multiplied by 1/N where number of samples is N in a single cycle.

4. Analytics Platform

Due to relational database management systems (RDBMS) inadequacy to offer analyzed contextual data from the stored data, a proper and a unified solution known as Analytic platform addresses users demands, usually large data-driven companies. Different tools are joined for making together the analytics systems having an engine to be executed, a DBMS to be stored, data to be managed, processes of data mining, mechanisms, and techniques for un-stored data that is yet to be obtained and prepared.. This could be delivered as a software-only application or as a software which is cloud-based, as a service (SaaS) given to organizations needing analytical information based on current data indications. The analytics database (ADBMS), the analytics platform DBMS component, is especially designed for administration in business and applications in analytics, that are concerned with data smart or data warehouse. It’s read-only system, and historical business data is stored in it, such as inventory levels or performance of sales. Cost effectiveness, performance, scalability, and ease of operation benefits over the conventional RDBMS is featured in it which makes the user able to view different range of analyzed information like total sales in a given time in contrast to any other desired period, getting visual cues like graphs making executives easily view trends and react accordingly to shift of market. Analytics platforms makes use of constructs of the container for securing and synchronizing different processes that run in parallel with furthermore processors. Besides, already available hardware that is also expensive, are used by these platforms as they could be deployed to other organizations because it is a paid service software solution.

4.1 System Architecture

Flow of information and electricity is ensured by Smart grids in both directions from utility to customer and vice-versa. Through smart meters and AMI (Advanced Metering Infrastructure), Communication occurs between the customers and the utility. Smart meters are able to provide real-time pricing, monitoring and controlling customer’s equipment, and detecting leak. Smart home meters are needed these days to be installed on any smart home. The core reason for this type of program is to deliver home inspection information about home furnishings such as status (On or Off), power consumption and in the event of malfunction, while providing a high level of comfort to the home residence. The use of electricity in residential buildings is increasing by day. Many researchers are investigating electricity consumption’s percentage and its impact on national GDP.

Concepts of Central architectural and their interaction is captured by representators of system. Of all the sub system components that are connected, a unified and unambiguous representation is allowed by smart grid architecture. Another challenging task is to use symbols and flow diagrams to describe architecture. Preciseness, Level of detail, and completeness are the differences in between many documents of architecture. Guidelines for documents of architecture are well defined to balance with explanations of high level and detailed descriptions. The concepts of software architecture can be improved to the ULS smart grid systems. Smart gird architecture bridges traditional power system automation with cloud systems and DERs. Principles of architecture towards arrangement of layers of software and grid sub-system interfaces are layed down by standards whose purpose is for innovations to be catalyzed, best practices to be highlighted, and global markets to be opened for Smart Grid systems and devices. However, these viewpoints of architecture and their granularity level needs to be analyzed carefully in engineering power with information technology.

Software algorithms interfacing with actuators and grid sensors realize the features of smart grid. Operating system enables the drivers on device ensuring the real time control and smart gird system's operation. 3 prominent layers of distributed software architecture contains these components:

Application layer: This Implements the functionality of actual software that comprises of sub-layers for instance service layer, component layer etc. Specific features of smart grid, for example, load forecast and management of demand are realized. Separation of layers that are connected is ensured by the components of abstraction, while permitting the data communication. Communication between the components of individual software is ensured by RTE, and with operating systems help, it also handles execution of the components of software. Huge wind flow availability informs about the static loads. Relevant operations and sub-systems are synchronized. Effective and intelligent energy distribution is performed by architectural help to end users. Renewable sources of energy and their distribution and generation is integrated with its help. Also, the utility control center and consumer communicate through the help of desired network. This may lead to services of electricity becoming more efficient, cost-effective, reliable, self-optimizing, self-repairing, and conscious in environment. Smart grid architecture has 2 major objectives: 1. Management on how to utilize energy and distribute it to ensure balanced supply and demand. And 2. Ensuring grid's availability and reliability, autonomous and continuous monitoring, control of the grid and its measurement. To obtain this objective, smart grid requirements are analyzed in detail for software system and networked sensors' optimized performance is undertaken, that is explained in the coming section.

Service (Communication) layer: It connects to many layers with a protocol of agreed information exchange and realizes the functionality to abstract details from modules which are beneath them architecturally. The key modules are, Operating systems (OS) interface, the communication protocol interface, and services that are not depended on device. Energy customers and suppliers are located in a smart rid environment distributively, the network of communication will assume a structure of hybrid with many edge and core networks connecting all the customers and suppliers.

Device (Physical) layer: It's a physical layer consisting of the modules that has direct access to the peripherals and microcontrollers. Base layers contain all sensor interfaces and device drivers.

4.1.1. IoT AP Architectural System

An IoT AP is proposed by this study, unified with Wi-Fi and Ethernet communication interfaces with linked protocols, which can help us build a better life. Proposed IoT AP architectural system and its functions are introduced in Section 4.1.1 and Section 4.1.2 describes architectural system in detail.

4.1.2 IoT AP Functionality

Ethernet comes first allowing connection of AP to Internet; Wi-Fi comes second, providing Internet via an AP for handheld devices, esp32 microcontroller being characterized by low-power and for monitoring of environment or detection of event, it's normally rooted in sensors. Although, it is not able to allow communication in between different network protocols by using a traditional access point. Thus, for building a better life. Such problems of heterogeneous network must be solved.

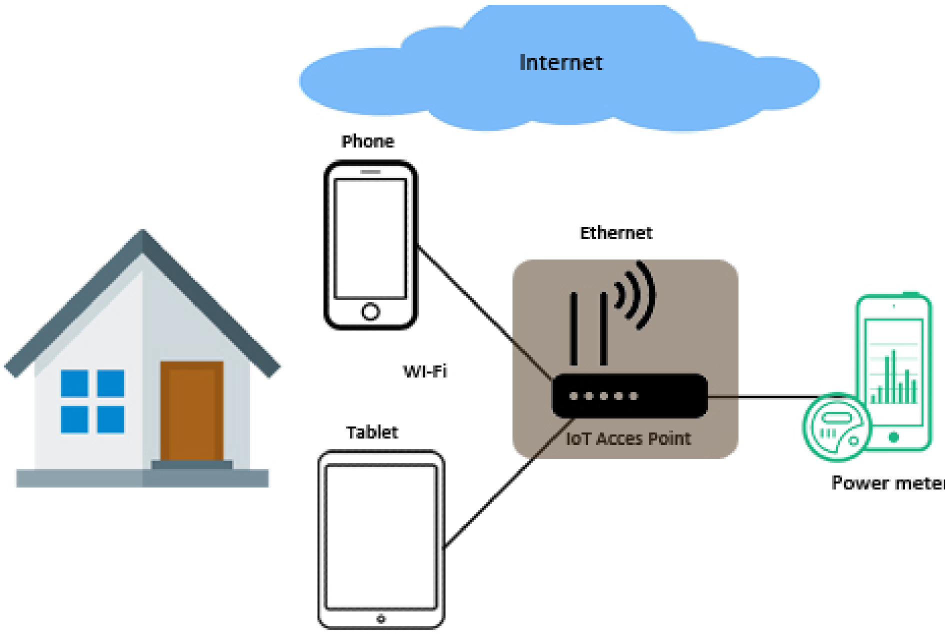

Figure 12 Organized connection between IoT

To enable communication between each other within a heterogeneous network, three main functions are provided by an IoT app. For starters, data conversion services and internet connection is provided on wi-fi. Secondly, an IoT network is established allowing communication of home devices in between each other by using its wireless protocol. Lastly, a consumer interface dashboard is provided, so that through internet, the consumers at home can control Smart Power Meter device remotely. A small energy requiring wireless interacting protocol with transmissions in short-range and its association allows developers to carry out most of its compatible products. ESP32 also provides many advantages, like low cost, low energy, low difficulty, safety and trustworthiness. With the firmware upgradation, this study, offers the IoT AP design and implementation. ESP32 wireless protocol is integrated in existing wireless AP for development into an ap in which Wi-Fi wireless communications and capabilities to access Internet are provided. Manipulation of the ESP32 devices from the illegal users can be prevented at home, for which, this thesis further implements technology of the universal plug and play (UPnP) in which only through a LAN, a user can access the device. Home appliances can be controlled remotely and privately if technology of virtual private network (VPN) can be implemented by the remote users thereby establishing a network connection that's private for the IoT AP for Power Meter devices assessment. That’s why VPN technology isn’t discussed further in this study.

In IoT smart home applications, applied technologies are integrated in the IoT AP that's proposed. Figure shows that the 3 forms of interactions among the assorted network are provided by IoT AP, for example Wi-Fi, Ethernet and the ESP32. Home devices can be controlled by ESP32 protocols, which are low energy requiring, because of the home network through this IoT AP. Later, with the help of IoT AP embedded with ESP32 agent, the local far-flung consumers are capable of controlling and accessing the home devices that are based on ESP32.

IoT AP development is shown in this study where we introduced the current Wi-Fi AP with the ESP32 agent. ESP32 devices can be controlled by remote users, which are connected to Internet. Also, managed mobile devices are capable of accessing ESP32 devices through the protocol of UPnP. Imagine that the user wants to control other ESP32 devices, locally, by sending commands via Wi-Fi or Ethernet to the IoT AP. Figure shows that the Channel Allocation Module includes the feature of negotiating the utilization of channel amongst ESP32 networks and Wi-Fi. Also, the Emergency process Module shifts the ESP32 network to emergency mode from energy-saving approach, enhancing the chance for sensors to report readings of their data.

The ESP32 agent plays device role between the USB transfer machine and the ESP32 device. ESP32 agent connects to the ESP32 device providing the ESP32 regulator facility to consumers over the Web.

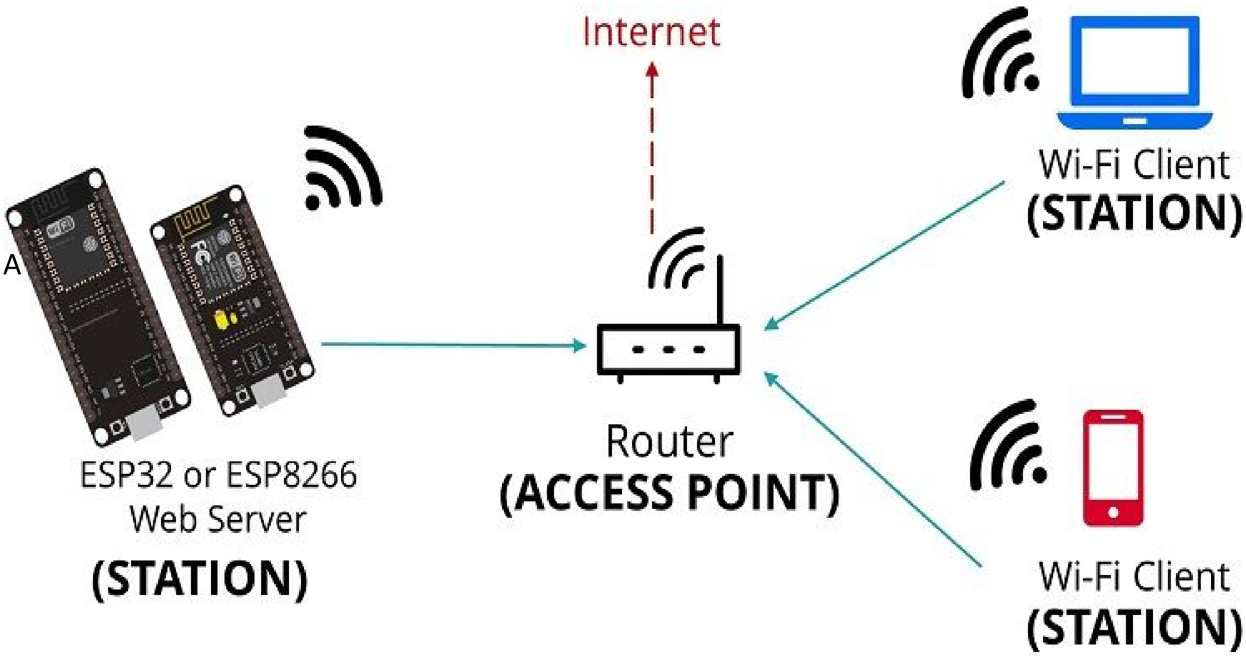

Figure 13 Communication between ESP and Users

AMI systems contain hardware, software, sensors, controllers, consumption displays, communications, meter figures supervision software, customer systems, business structures and data mining software. Two-way communications with the meter are provided, allowing to send commands from the utility center to the smart meter for different reasons, like regulating of actual-time values and fluctuating the readings rate between others. The system amongst the utility centers and smart meters allows collection of data and then its distribution to suppliers, customers, service providers, and utility companies. Classification of all components is allowed by a layered architecture and it's interfaced into different categories according to their purposes and features. The proposed architectural communication contains any type of remote/local communication. Each particular case has different technology for communication, that

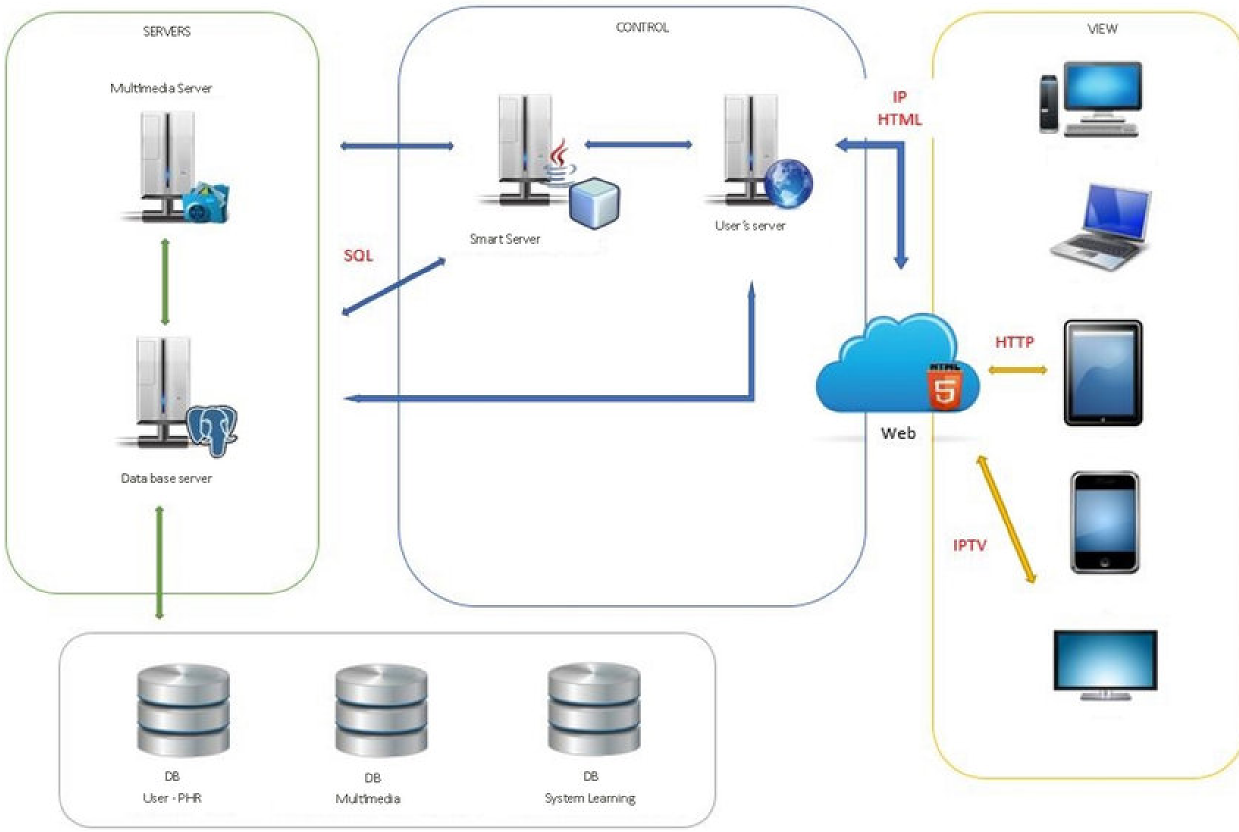

Figure 14 System Architecture (Google Images)

relies on the multi-standards selection methods and environmental conditions. Qualitative and quantitative variables are considered to select the suitable technology for communication. The important ones are the distribution and location of smart meters, meter-hub, restrictions, the urban context, the communication prices, and the ability to be measured. Protocols of current registered smart meter communication are solely suitable for deployments for a specific geographic context or with few smart meters. Different manufacturers have different meters having different features. Thus, a certain solution or meter may or may not be the best choice depending on what is.

4.2 Database Design

Web based applications and their data management needs have changed dynamically in the past few years. Variety of features and strict data consistency is provided by the relational databases. Due to massive cost of storing and manipulating data in classical relational database systems, NoSQL databases have been developed. NoSQL databases provide more scalability and heterogeneity when compared to RDBMS. MongoDB, a NoSQL database provides high scalability, performance and availability. MongoDB is a document-based NoSQL database designed for Internet and web-based applications. Data model of MongoDB is easy to build on due to its inherent support for unstructured data. MongoDB does not require costly and time-consuming migrations when application requirements change. MongoDB's documents are encoded in a JSON like format called BSON. This paper describes the advantages of MongoDB when compared to other NoSQL databases and its applications in sentiment analysis.

During the last decade, there was an enormous growth in the database sizes. This made monolithic database systems struggle to keep up with today's requirements. Products based on the well-known RDBMS traits are available today. But applications those require data and or functional partitioning, either because of the sheer size of the data or for the purpose of load balancing have to rely on custom built relations or utilize alternative database systems. Since distributed partitioning implementation has become a real challenge with the high demand for multi-machine databases, a whole set of NoSQL (not only SQL) databases have emerged to fill the gap of RDBMS. Common features of NoSQL products are the divergence from the relational data model, simplification of transactional model and transaction processing and most importantly the shift to the imperative programming model from the declarative style SQL language. Relational databases are often being replaced by other viable alternatives, such as NoSQL databases, for reasons of scalability and heterogeneity. MongoDB, a NoSQL database, is an agile database built for scalability, performance and high availability. It can be deployed in single server environment and also on complex multi-site architectures.

MongoDB is told as an open source and independent database technology which promises a structural data that is flexible, capabilities of comprehensive query, and an architectural model that ensures high availability and scalability. The importance is shown of presenting MongoDB's statistics, query and architecture models, accompanied by few additional characteristics. It is a text-focused record, and thus, for storing data, as a primary structure, documents are used. MongoDB uses other concepts for data modeling, for example, assemblies and records. These perceptions are depicted in the Figures 15 and 16.

Figure 15 Database collection

Figure 16 Database Users

```
__MongoDB.collection('device_data').find(document).sort({_id:1}).limit
(15).toArray(function(err, result){
if(err){
return res.render('index', {error: err})
}
```

Listing 2 Mongo DB Collection Code

In MongoDB's context, a database is the external vessel comprising of clusters. Catalogues are the MongoDB equals of key spaces, and so encompasses data of the complete usage. An assembly is joining of MongoDB files. To store a single unit of data, document is a basic structure. MongoDB files utilize the dual JSON (JavaScript Object Notation), BSON, plan that consists of groups of field pairs. Also, a unique identifier is needed by each document. A document can store possible values like basic arrays, data types and even objects.

```
_id: ObjectId("5d5e9b0c935bd92ff43c020f")
device_id: "84:0D:8E:AB:E5:10"
time_sent: 2019-08-22T13:39:24.616+00:00
irms: 1.31
```

Figure 17 Stored Information Sample

Data models are designed to be quite flexible in order to support the storage needs arising from applications dealing with highly heterogeneous data. Also, the wide-spread use of dynamically typed scripting languages has made less strictly structured background storage system favorable. While a highly generic data model looks reasonable from the aspect of the client, efficient server-side processing makes certain restrictions on the data model necessary. As a result, many NoSQL systems offer semi-structured models and list-like data types.

Document Databases: These were inspired by Lotus Notes and are similar to key-value stores. The model is basically versioned documents that are collections of other key value collections. The semi-structured documents are stored in formats like JSON. Document databases are essentially the next level of Key/value, allowing nested values as-sociated with each key. Document databases support querying more efficiently. Examples: CouchDB, MongoDB

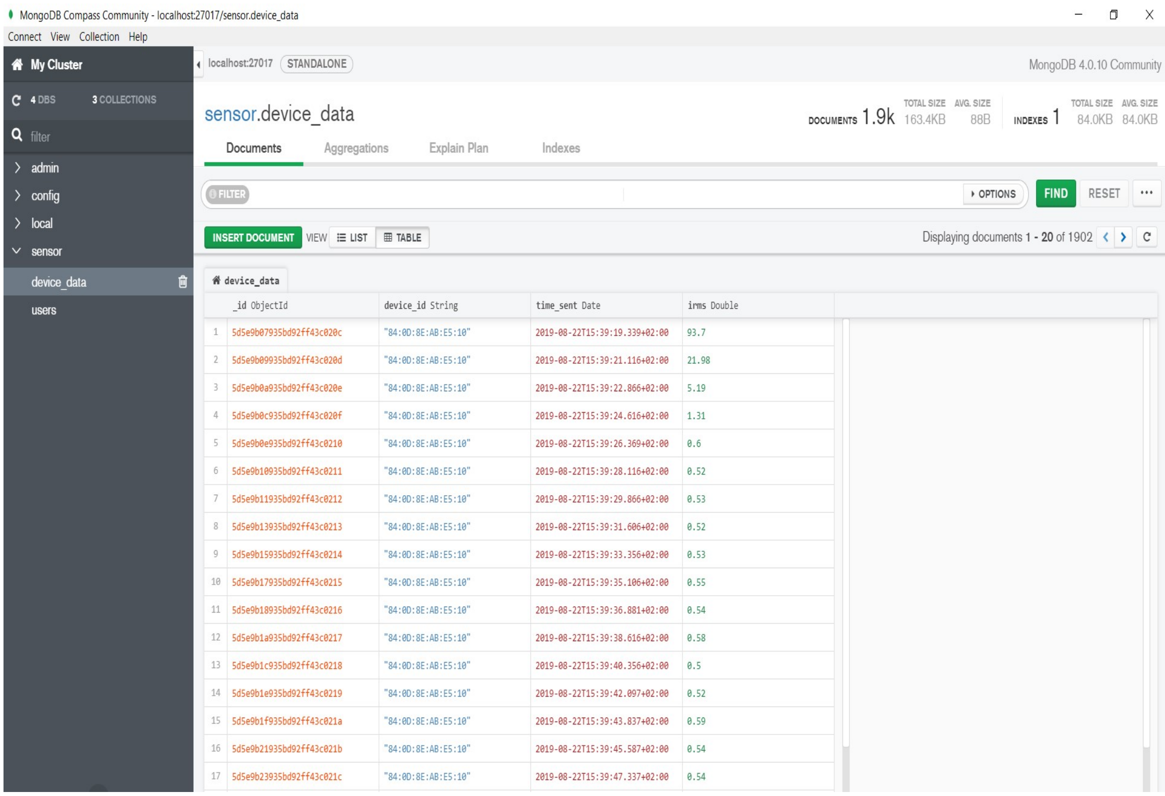

Figure 18 Example of Device Data Storage

MongoDB data model makes few points. First, observe the absence of a scheme which describes the text construction inside a cluster. A standard guide for storing files of the similar purpose and structure in single group is present, but nobody prevents document storing with diverse properties and content in a same group. Secondly, formatting of files permits graded statistics by the nesting abilities. And, constructed on their complete arrangement, JSON is designed to define things, so this model integrates fine with material-focused program design.

Lastly in end, the model needs the relationship to have a clear need, either by rooted files (subtitles) or by providing additional files utilizing their exclusive identifiers. In the example above, both methods are used, related to the specifics of every film. Every technique consists of its own advantages and disadvantages, but generally, encoding works best in minor, stable natural files, while the citations are more beneficial for bigger files having dynamic information, and are probable to be a secluded enquiry. Progresses that happen in the database technology databases are becoming more and more popular now a days. MongoDB is the one of them that uses the cloud-based NoSQL database. Strongly data modelling strategies for relational and non-relational databases differ from one another. MongoDB modeling of data bound up with database that depends on the data and characteristics of MongoDB. Due to variation in data models MongoDB based application performance gets affected. There are two different modeling styles as embedding of documents and normalization on collections. The embedding features that we may face in situations where documents grow in size after creation which may degrade the performance of a database. In MongoDB maximum allowed document size is limited. With the references we can get maximum resilience than embedding but client-side applications do matter follow-up queries to resolve the references. The joins in this case cannot be effectively used. Hence there is need for defining the strategy of extent of normalization and embedding to get better performance in the mixed situation. Database research discussed here shows the variation in the performance along with the change in the modeling style with reference to normalization and embedding and it gives the base to find the rating of normalization and embedding for reducing query enforcement time. So, we in our project used Normalized Data Models. Using Normalized Data Models in our project was the best way that we can collect all the data by JSON and store them in our database. We didn't need so complex database for our first prototype. In the future as the project grows and gets funds then by growing the needs of community, we will have to switch into other databases. Here are some examples of codes developing the database as in Listing 3.

```
__MongoDB.collection('users').findOne(document, function(err,
result){
if(err){
return res.render('login', {error: err})
}
```

Listing 3 Database MongoDB

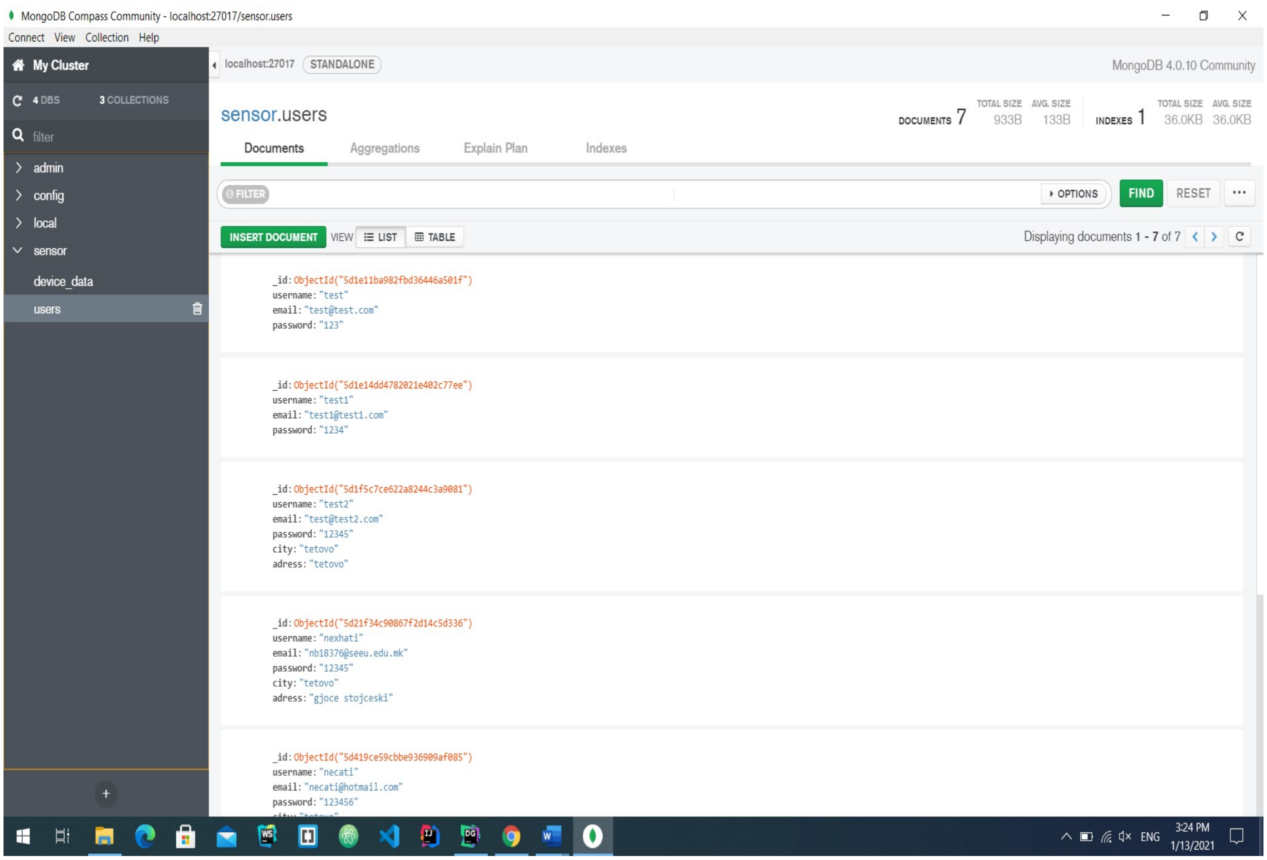

Figure 19 MongoDB Users

One more advantageous fact is that JavaScript code can be ran into the shell directly, including almost all of the components of language, for example, functions and loops. The query model of MongoDB is implemented in the supported programming languages APIs, but in the last section, they are very similar to the syntax. **T**herefore, learning a completely different language isn't required by the user from MongoDB querying. The shell-based notation will be used now for further discussion. Data model is mapped by MongoDB straight to its query model, so no surplus mappings nor terminology that needs to be told here. To understand queries in MongoDB, there are 2 important insights; queries comprises of certain parts and queries revolves about ascertaining (and getting) files. When a document is being retrieved from database, a document is also sent by one, containing some specified properties. That means, the queries comprise of documents. NoSQL systems offer much less functionality than traditional relation database management systems, especially in transaction isolation and scan operations. But they can be successfully used when complex database logic is not, but large-scale, distributed operation is an objective. MongoDB is an effective document-oriented database which can be used for analysis and other applications. JSON format of data stored in MongoDB helps in analyzing the data easily for further processing. In future we can analyze a greater number of features of MongoDB and compare with NoSQL.

4.3 Report Generation

In the Front-end part it was created with the intent of being a simple but useful tool for the final client, where are made available the instantaneous voltage and current readings, and a plot with data collected for an overall idea of the Smart Meter consumptions throughout the day. This study's main focus is to perform energy metering reports to the central server. As a solution, to perform the measurements, there are 2 ways: 1. Requesting measurements to a smart meter, and 2. Direct metering. Different tests were performed for different methods of measurement. For performing this test, Energy Meters that perform consumption readings, got a request. The prototype response consists of: 1. instantaneous current, 2. complete consumption, 3. instantaneous real power, 4. instantaneous power factor, 5. instantaneous main voltage and 6. instantaneous apparent power. An outer energy meter was used to calibrate our meter for the energy measurements. Several requests were performed with a calibration, obtaining the graphical consumption representation represented in Figure 16.

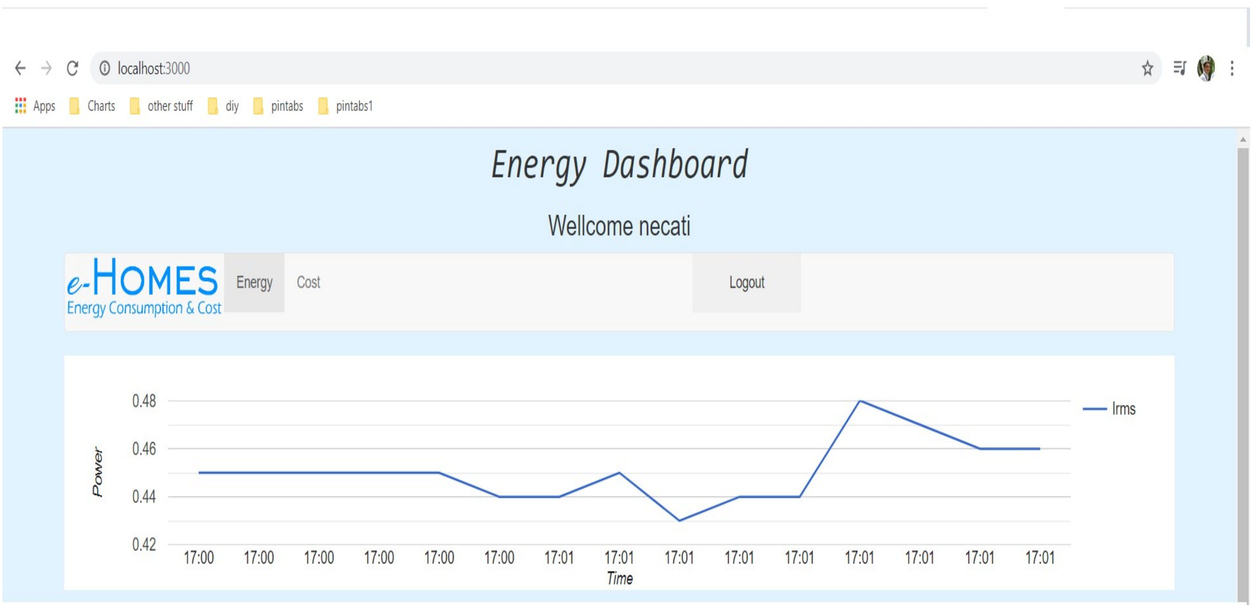

Figure 20 Graphical consumption representation in real time

In this case, a static plot was designed since these values are only updated once every 10 seconds. The plot presented in the Figure 20 has real data and is an accurate small-scale representation of the general consumption in a house, with higher voltage and lower current values during the night, and several current peaks throughout the day. To ensure a completely customizable solution, all Energy meter settings can be changed if needed. In our solution, it is possible to perform these changes locally, using a USB connection to access the option menu. To perform all the previous tests, several configurations were performed to prepare them. It was the main configuration feature used due to most of the Energy meter being connected directly to the laptop. However, several configurations were also performed remotely, using the Modbus protocol to more distant Energy meter that was not connected to the laptop during the performed tests.

There is a part of the code for data visualization of the graphs in the web.

```
google.charts.load('current', {packages: ['corechart', 'line']});
  google.charts.setOnLoadCallback(drawBasic);
  var chart, data;

  function drawBasic() {

        data = new google.visualization.DataTable();
        data.addColumn('string', 'Time');
        data.addColumn('number', 'Irms');

        data.addRows(device_data);

        var options = {
          hAxis: {
            title: 'Time'
          },
          vAxis: {
            title: 'Power'
          }
        };

        chart = new
google.visualization.LineChart(document.getElementById('chart_div'));


        chart.draw(data, options);
        startTimer();
```

Listing 4 Graph Visualization

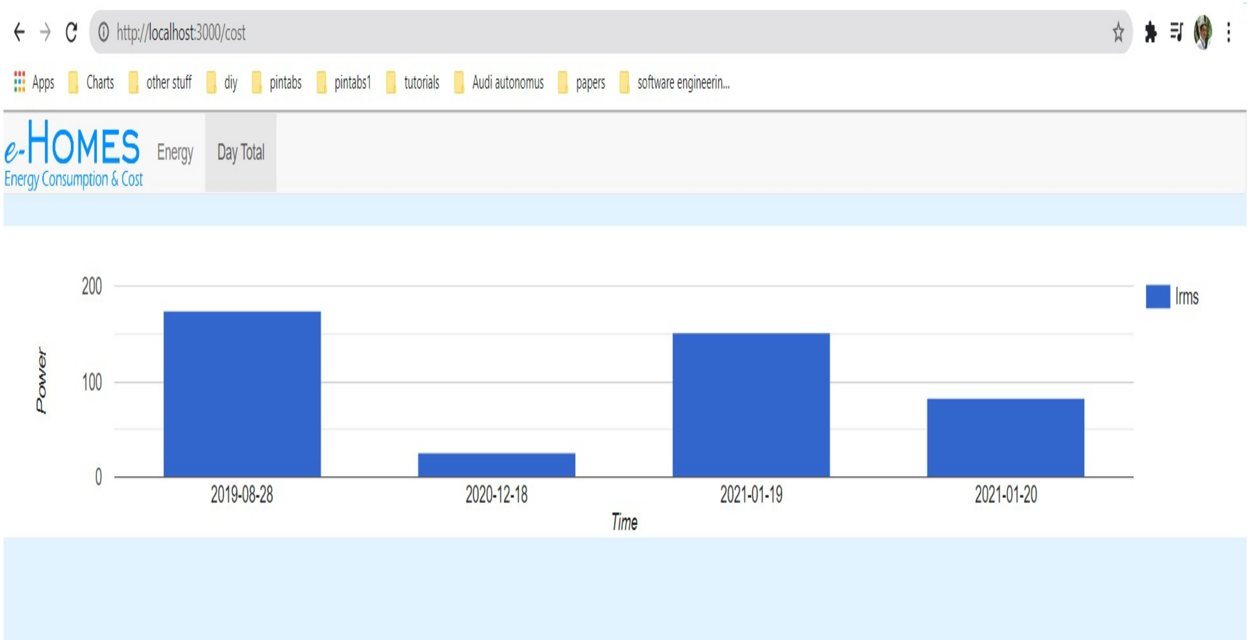

Figure 21 A screenshot of the power consumption daily

This is the intuition behind the data generator. Since electricity consumption mainly depends on daily operation, we start with a small seed of real information and create daily market profiles for each customer. In order to produce a new time series, we take a randomly selected user into a real dataset from the regular activity pattern and read the results within 24 hours.

5. Conclusion

With the work presented here, a solution of wireless energy metering is developed, which allows a tailored configuration and fast installation of the metering area. Meters' locations can be defined by client, thus allowing sub-metering, and can later adjust these locations with choice, for achieving a more precise sub-metering in areas that advises deviations or problems in potential consumption. Our solution's exciting feature is that it successfully incorporates the Modbus protocol atop RF protocol, that is tested and created over the ESP8266 (NodeMCU) microcontroller. The integrated solution allows the use of metering energy at cheap rates. Significant savings are allowed by small investments, as it can provide feedback to the users when energy is used and waste. Consumer savings joined with lower costs allow fast return on investment than other solutions. As compared to others, it is also very flexible, usually when you compare it to integrated solutions, where the optimization is tough, if possible, at all, while lacking the extra tools. If utilizing less expensive meters, the fitting costs could be overlooked, and fitting of multiple electric meters is taken into account without any difficulty, with less detailed meter information. This allows to provide a cheap solution for the customer as well as an accurate and adequate solution, and thus, better service. The main advantage of our solution is that depending on the type of metering solution installed on the client, our solution can be very expensive. Energy Meter Serial Brick has a production cost lower than Energy Meter Brick, thus, installing this model in areas where installed smart meter can lessen the final cost for the customer. Such benefits can be attributed to home equity, or to small and medium-sized enterprises. Open source software and Open-Hardware platforms offer new chances for designing the products that are not possible by one person. Such new opportunities have allowed us to build a program which has the ability to do comparison with the few current solutions in the marketplace and increase the properties by adding novel modules without any difficulty, bringing benefits for market competition. Moreover, the regulation of use can also be set up without any difficulty by addition of a regulator component which permits turning off or on any type of equipment, such as a radiator or lamp, or controlling uncontrolled consumption of power, such as electric ballasts that allow blurring of light, all this in addition to being a metering solution. Such remote control can allow for fully changing conditions and increase occupancy comfort, while enabling effective and efficient energy storage.

The developed work using open solutions allowed us to achieve interesting results were achieved by the allowance of developed work using open solutions. In greater detail, this works' achievement are as followed:

In this thesis, **Energy meter prototype** is developed and tested successfully. With setup of this scenario, for further development, a starting point was attained, confirming that energy consumption can be controlled with electronics and open hardware.

In a single Arduino microcontroller enabled us to develop an Energy meter that can use all modules at once. However, there wasn't any flash memory limitations, it was possible to upload all the code needed to operate with all the modules at once, where each one uses combinations of this low-cost hardware.

During this thesis, several problems occurred. However, all of them were overcome, having as end result the creation of several Energy meter prototypes, as well as some valuable lessons:

Nothing is as simple as it seems In the beginning, we started with the collection of the components needed for the project, it took us a long time for collecting all of them because we needed to wait for the components to arrive from china. During this time, we had a research about how to develop the prototype, used hardware caused a major problem on performing measurements, which was overcome by adapting the resistors to calibrate the measurements. During this time, another problem occurred. When connecting the resistors into breadboard with Arduino board, it was measuring less than it has to be, thus causing problems, so we needed to search about the correct resistor to have better measuring from the sensor. **Uploading code to multiple Arduino is not simple and is time consuming.**

Several Arduino boards are used, causing a problem in this earlier stage, where the code upload must be performed to all, and each one uses a different COM port. Since there were several Energy meter, each one with its own modules installed, and a single sketch to be uploaded, every time that an upload had to be performed, the sketch definitions had to be changed, and the COM port also had to be changed in order to upload the sketch to the specific Arduino board.

Besides all these problems, in the end a fully functional system that collects data from the microcontroller and a web-based data analytics platform that will present useful consumption metrics was successfully developed. The big lesson is that in this new age of open electronics platforms, everything is possible. Even if we do not have specific hardware to replicate a solution, a similar hardware can still be used, adapting its behavior to match a desired function. In this new age, where the Internet in the palm of our hands, this solution can also be remotely controlled, thus giving us control not only of our virtual world, but also of our real world, merging both to make life better.

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