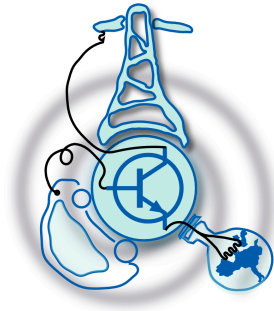


Integration of data reporting and visualization of an Energy Management System for Buildings

by
Nahid Nasrin



Submitted to the Department of Electrical Engineering, Electronics,
Computers and Systems
in partial fulfillment of the requirements for the degree of
Erasmus Mundus Master Course in Sustainable Transportation and
Electrical Power Systems
at the
UNIVERSIDAD DE OVIEDO

September 2020

© Universidad de Oviedo 2020. All rights reserved.

Author

Certified by

Dr.Jorge García Garcia
Associate Professor
Thesis Supervisor

Certified by

Dr.Islam El-Sayed Mahmoud Hassan
Postdoctoral Researcher
Thesis Supervisor

Integration of data reporting and visualization of an Energy Management System for Buildings

by

Nahid Nasrin

Submitted to the Department of Electrical Engineering, Electronics, Computers and Systems

on September, 2020, in partial fulfillment of the requirements for the degree of

Erasmus Mundus Master Course in Sustainable Transportation and Electrical Power Systems

Abstract

The world is becoming more cyber-centric, less disconnected as well as extra sustainable. Energy system have become as the primary resource of the infrastructure of the society. Most European Buildings are a hub of energy related wide variety of data resources. The data can be gathered from numerous sectors such as smart meters, sensors, IOT related devices etc. The present capacity of the building sector is considered as below bar . In EU, as it accounts for nearly 40 Percent of the energy consumption, it should have a key effective energy management policy. If we can oversee this energy and other requirement in buildings skillfully and brilliantly, it will be able to acquire substantial blessings in a long run. A building energy management system is an advanced method to monitor and control the building's energy requisites. Besides energy management, the system can control as well as monitor a significant range of various facets of the building irrespective of their utilization i.e. residential or commercial.

The project contains an existing energy measurement procurement system with a commanding assimilation of a system that permits us the analysis of the energy consumption in a building, rendering tools for decision making. The visualization system will give the opportunity for the amalgamation and characterization of information coming from data acquisition units, DAU , which are executed either by real smart meters or industrial energy measuring units (implemented in the real building). This can also be done by means of virtual units (based on simulation models, specifically being able to intermix the simulation of consumption from Elevators as a basis of former projects).

Thesis Supervisor: Dr.Jorge García Garcia

Title: Associate Professor

Thesis Supervisor: Dr.Islam El-Sayed Mahmoud Hassan

Title: Postdoctoral Researcher

Acknowledgments

This thesis came into reality with the sincere support and help from many individuals. I would like to extend my heartfelt appreciation to all of them.

First and foremost, I would like to offer my deepest gratitude to Almighty Allah for the wisdom he bestowed upon me , the strength , peace of my mind and good health so that I could finish this research within time. I am forever indebted to Almighty for always showing me the rightful direction in my life and always providing me opportunities more than I can ever dream of.

Secondly, I am greatly obliged to my thesis supervisor, Dr. Jorge García Garcia, for his continuous support for my Masters study and research .He always convincingly conveyed a spirit of adventure in research and study, and an excitement in regard to teaching. Prof. Jorge has skilfully taught me the methodology to carry out the research and to present the work as clearly as possible. It was an honor as well as an immense privilege to pursue my research under his supervision. In addition to, I would also like to show my gratitude to Dr. Islam El-Sayed Mahmoud Hassan for his guidance throughout my thesis. His dynamism, sincerity, vision and motivation towards research has deeply moved me. He encouraged me to partake various online programming classes so that it could improve my skill and knowledge. Without his guidance and persistent help , this dissertation would be an impossible dream.

I would like to convey thanks to the University as well as my STPES colleagues specially Mhret who helped me with valuable suggestions and help in every step of these two year study. We have become a family through this process.

Last but not the least, I am extremely thankful to my parents and my siblings for their love, prayer, caring and sacrifices for educating and preparing me for my future. They have given me constant guidance in every step of my life. I owe a lot to them. I wouldn't have been here if they did not show their belief and confidence in me. .

Contents

| | | |
|----------|---|-----------|
| 1 | Introduction | 15 |
| 1.1 | Comprehensibility of the prevailing state of the project: | 16 |
| 1.2 | Objectives and Goal of the thesis: | 18 |
| 1.3 | Methodology of Thesis: | 18 |
| 1.4 | Thesis Structure: | 19 |
| 2 | Energy Management System -A Compendious Study | 21 |
| 2.1 | What is Energy Management System | 21 |
| 2.2 | Energy Management system in Building : | 23 |
| 2.2.1 | Definition of Energy Management in Buildings: | 23 |
| 2.2.2 | Difference between BMS and BEMS: | 23 |
| 2.2.3 | The goals of BEMS: | 24 |
| 2.3 | Energy Management system overall Scenario: | 25 |
| 2.3.1 | BEMS in EU: | 25 |
| 2.3.2 | BEMS in WORLD: | 26 |
| 2.4 | Literature Review for the project: | 27 |
| 3 | Structure of the Project | 33 |
| 3.1 | Brief Discussion of the project: | 33 |
| 3.2 | Smart Meter: | 34 |
| 3.3 | Advantages and Disadvantages : | 35 |
| 3.4 | Types of Smart Meter Used in Thesis : | 37 |
| 3.5 | Server: | 39 |

| | | |
|----------|---|-----------|
| 3.5.1 | Server in the thesis : | 39 |
| 3.5.2 | What is MODBUS: | 42 |
| 3.5.3 | Application of MODBUS Protocol: | 42 |
| 3.5.4 | MODBUS data type: | 44 |
| 3.5.5 | MODBUS TCP/IP Protocol: | 44 |
| 3.6 | Database Management System: | 44 |
| 3.6.1 | Types of DBMS [1]: | 46 |
| 3.6.2 | SQLite database management system : | 46 |
| 3.6.3 | Why we used SQLite in our project: [2]: | 46 |
| 3.6.4 | Binary Database : | 48 |
| 3.7 | Client / Front end : | 49 |
| 3.7.1 | HTTP Requests: | 49 |
| 3.7.2 | Request categories: | 50 |
| 3.7.3 | . Profile of the Users: | 51 |
| 3.7.4 | Data History: | 51 |
| 3.7.5 | How data history is presented in the project: | 52 |
| 3.7.6 | Real time data of Smart meter : | 52 |
| 4 | Necessary tool of the Project | 53 |
| 4.1 | Node.js : | 53 |
| 4.1.1 | Characteristics of Node.js : | 53 |
| 4.1.2 | Application of Node.js : | 55 |
| 4.1.3 | Administrating Node.js in The Project: | 56 |
| 4.2 | Express.js : | 56 |
| 4.2.1 | Introduction to Express.js : | 56 |
| 4.2.2 | Applications : | 56 |
| 4.2.3 | Pros and Cons of Express.js: | 57 |
| 4.2.4 | Application of Express.js in our project : | 58 |
| 4.3 | Angular: | 59 |
| 4.3.1 | Introduction to Angular : | 59 |

| | | |
|----------|--|-----------|
| 4.3.2 | Features of AngularJs: | 60 |
| 4.3.3 | Pros and Cons : | 60 |
| 4.3.4 | The motive behind instituting Angular for this project: | 61 |
| 4.4 | Postman : | 62 |
| 4.4.1 | Introduction to Postman Tool: | 62 |
| 4.4.2 | Advantages : | 63 |
| 4.4.3 | Disadvantages : | 63 |
| 4.4.4 | Features of Postman: | 63 |
| 4.4.5 | The necessity of Postman in our project : | 64 |
| 4.5 | Plotly : | 65 |
| 4.5.1 | Introduction to Plotly: | 65 |
| 4.5.2 | Library of Plotly : | 65 |
| 4.5.3 | The main products of Plotly: | 66 |
| 4.5.4 | The reason behind selecting Plotly as Visualization Technique for our Project : | 67 |
| 5 | Validation through Implementation And Results : | 69 |
| 5.1 | Hardware Implementation: | 69 |
| 5.2 | Implementation Of The Project -Software Part And Result | 74 |
| 5.2.1 | User Interface | 74 |
| 5.3 | The Dashboard: | 75 |
| 5.3.1 | Comparison Between Device | 88 |
| 6 | Conclusion and Future Work | 91 |
| 6.1 | Conclusion: | 91 |
| 6.2 | Future Work : | 92 |
| A | Tables | 95 |

List of Figures

| | | |
|-----|--|----|
| 2-1 | : Structure of energy management [3] | 22 |
| 2-2 | : BEMS market in EU [4] | 26 |
| 2-3 | : : Present scenario of BEMS in the world market [5] | 26 |
| 3-1 | The framework Of the Project | 34 |
| 3-2 | Block Diagram of a typical Smart meter [6]. | 35 |
| 3-3 | Connection of Smart Meter with Grid and Loads [7]. | 35 |
| 3-4 | a) Simple diagram of CVMk2 (Frontal View) [8], b) PM 710 [9] ,c) CEM C20 [10], d) PAC 4200 [11] | 40 |
| 3-5 | Server Structure [12] | 41 |
| 3-6 | Structure of Server in the thesis. | 41 |
| 3-7 | Block-diagram for MODBUS System [13] | 42 |
| 3-8 | Simple Structure for MODBUS TCP [14] | 45 |
| 4-1 | Operation of Node.js Sever [15] | 54 |
| 4-2 | application of Node.js [16] | 55 |
| 4-3 | : Applications of Postman [17] | 62 |
| 4-4 | : Library for Plotly graphs [18] | 66 |
| 4-5 | : Data of Election Results is plotted in bar using Plotly [19] | 66 |
| 5-1 | : Server. | 70 |
| 5-2 | Smart meter Power reading of phase 3 | 71 |
| 5-3 | Smart meter Current, Voltage and PF reading of phase 3 | 73 |
| 5-4 | The User Interface | 74 |

| | | |
|------|---|----|
| 5-5 | The Log-In Page | 75 |
| 5-6 | The Profile Page | 76 |
| 5-7 | The User List | 77 |
| 5-8 | Removing any user from the website | 78 |
| 5-9 | The Device List | 79 |
| 5-10 | The 4 type of Smart Meter List | 79 |
| 5-11 | Confirmation for adding device to a smart meter | 80 |
| 5-12 | Process of Visualization [20] | 81 |
| 5-13 | The Visualization Section | 82 |
| 5-14 | The data for a certain device | 82 |
| 5-15 | The data visualization for various time period | 83 |
| 5-16 | The data for 1 hour | 84 |
| 5-17 | The data for 1 day | 84 |
| 5-18 | The data for 1 week | 85 |
| 5-19 | The data for 1 month | 85 |
| 5-20 | The data for 1 year | 86 |
| 5-21 | Real Time data Configuration | 87 |
| 5-22 | Table for Real Time data Configuration | 87 |
| 5-23 | The data for voltage comparison between 2 devices | 88 |
| 5-24 | The data for current comparison between 2 devices | 89 |
| 5-25 | The data for THD comparison between 2 devices | 89 |

List of Tables

| | | |
|-----|---|----|
| 3.1 | MODBUS data types [21] | 44 |
| 3.2 | Size Comparisons for storing data of meters | 48 |
| 3.3 | Data write Speed | 48 |
| 5.1 | Profile of Visitor | 77 |
| 5.2 | Real Time Data Management | 86 |
| A.1 | Data Reading Speed | 95 |
| A.2 | Session. | 95 |
| A.3 | User Management. | 96 |
| A.4 | Presentation of Data History. | 96 |
| A.5 | Device Management. | 97 |
| A.6 | data history Management. | 97 |

Chapter 1

Introduction

Electrical energy is deemed as one of the importunate energies of the today's world. Though modern era can not be reinvigorated without the boons of electricity, nonetheless, it is sadly amongst the most mismanaged blessings of the world. The energy usages in both residential and commercial buildings can be epitomized as very high rate ; one of the supreme entities in the entire world. Specially commercial facilities , for example - residential hotels; deplete a plethora of energy which is approximately more than 60% [22] of the equivalent sized domiciliary dwelling. For the purpose of superintending the energy expenditure of the facilities, the necessity of establishing a visualisation system is in crying need. One of the substantial vigour as provision for catalyzing a environmental friendly as well as energy efficient society could be the covenant of a smart, indomitable and unequivocal near future.

Energy efficiency in buildings leans on the mechanism of the building operation. As a consequence, **Building Energy Management System** or **BEMS** is proved to be a pivotal element for the smooth sailing of this operation. The abatement in total energy demand ascribed to the incorporation of BEMS results in an upthrust security of the immense disburse of energy.

Data analysis system supports in better understanding of the systems and helps to dredge up inadequacies as well as abnormality in the system. The energy companies are being promoted from these smart analyses which entail of database algorithms and trailblazing visualizations.

One principle feature of the BEMS is that it is competent enough to contribute real-time and comprehensive data on energy consumption to the amenity operator. Ergo, it leads to assurance of energy efficiency and reduction in environmental pollution to a great extent eventually. For example, as BEMS helps in the growth of proper usage of energy, it yields in subservient carbon dioxide level and low SO₂ emissions [23].

Therefore, these numerous perks of BEMS lead to the implementation of it in an existing system and afterward possible visualization of data; which are being set as the ultimate goals of this master thesis .

1.1 Comprehensibility of the prevailing state of the project:

Any **energy management system (EMS)** is based primarily on measuring and storing information that is able to assess the energy consumption in the target application.

In order to procure the targeted benchmark, the data of **Thyssenkrupp Elevator Innovation Center (CITI TKEIC)** has been forked out with an ample measurement framework. This measurement infrastructure has been made for the purpose of attaining the required electrical magnitudes, with a satisfactory level of precision, for the most significant consumption points in the building, to grant for the chronological analysis of them.

Heretofore, the following information has been provided:

1. The preminent energy consumption at the primary building, accompanied by the UPS system and at the prototyping plant.
2. Consumption of the heating and air conditioning systems.
3. Measurement of consumption at presumed locations, such as climatic chamber, laboratories and/or individual consumers such as workshop test equipment.

The current EMS supports different models that have been installed and showcases

maximum flexibility in assigning the measuring equipment to the defined point of consumption.

1.2 Objectives and Goal of the thesis:

The objectives of this is the homogenization of data from database management into the a online user -interface and the measured data on servers is then evaluated and visualized in info-graphical format to exhibit different information such as voltages, power factor and energy consumption of the three-phase AC grid line.

To fulfill this objective, the possible goals have been set as:

- To understand the detail structure of existing project and encompassing it perfectly in the ongoing masters thesis and possible further expansion of the existing project.
- To undergo a standardized research to full apprehend the overall scenario of energy management system(**EMS**) and its exigent pertinence in increasing the energy efficiency as well as in decreasing the pollution from environment.
- To carry out multiple veracious sessions in understating the different software that been employed in the thesis.
- To be acclimatize with **Database Management System (DBMS)**.
- To connect the smart meter with server for the implementation of the thesis.
- To acquire the required values from smart meter.
- To test and obtain validation of the result by integrating multiple users and devices from the website.
- And finally yet importantly to plot the data in line charts in real time as well as for past data eventually.

1.3 Methodology of Thesis:

The present thesis has been proportioned into two arrangements:

- Incorporating data for database management: preferably SQLite and Binary

- Visualization of the collected data through a data visualization gimmick. In this case, 'Plotly' has been set as our primary paraphernalia

1.4 Thesis Structure:

The rest of the chapters are organized as demonstrated bellow :

Chapter two depicts the compressed explication of Energy Management System in Building- its objectives and deployment in our diurnal bustle. It also contemplates the present scenario of building energy management system or **BEMS** in whole world , accompanied by a detailed outline of **European Union** or **EU**.

Also this chapter portrays a detailed literature review regarding the ongoing scholarly research in various aspects of building energy management system. The chapter also indicates possible reason for undertaking this specific thesis.

Chapter three has illustrated the overall structure of the project conscientiously. The thesis consists of three primary parts-smart meter, server and client. A rigorous study has been carried out in all three parts with brief description on **MOD-BUS** and **SQLite** database.

Chapter four discusses various necessary tolls for the projects. It also sheds a light on the merits , demerits and application of multiple software being utilized in this thesis.

Chapter five emphasises on the implementation of the project-both hardware and software. It also discusses the results obtained after the implementation.

Finally Chapter six announces the conclusion of the thesis with remarks of possible future works encompassed .

Chapter 2

Energy Management System -A Compendious Study

2.1 What is Energy Management System

Energy means the ability of a physical system to execute work. We can find energy in various formations i.e., electrical heat, light, mechanical energy, potential energy etc. Total energy in a structure is constant- it can just transform form one form to another: according to the law of reservation of energy. For example, when we turn on the light in our room, energy converts from electricity to the form of light which is a form of electromagnetic energy .it is an energy which is created from light or electromagnetic waves.

When two billiard ball hits one another, they may come to stand still, which results in energy transforming into sound with some of them converting into heat on the verge of collision point. Heat energy or we can say thermal energy, indicates the temperature variation between two points. Nuclear energy can be defined as the energy coming from changes in the atomic nuclei. It also originates from nuclear Chemical energy Chemical energy which results from the spontaneous chemical reactions between two or more atoms or molecules. Energy Management is established as "**The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or**



Figure 2-1: : Structure of energy management [3] .

reducing total costs of producing the output from these systems”. [24].

Energy management system provides prudent planning, administration and constant appraisal to decide whether energy saving plans execute through different ways such as:

- a Application of technologies dedicated for energy saving.
- b Behavioral modification schemes.
- c Property management actions.

Machine-learning, big data and visual analytics are at the center of energy management strategies. They are said to ensure the instruments required to apprehend data-driven rules. The decisions are mostly about fruitful energy management enactments, executions and exertions. Lately, cloud-based energy management systems bestow the capacity to control HVAC and other energy-consuming apparatus from afar; accumulate precise, real-time data for all the equipment’s; and initiate intelligent, exact, concurrent direction on detecting and conquering the most fascinating savings opportunities [24].

2.2 Energy Management system in Building :

2.2.1 Definition of Energy Management in Buildings:

The service, financial and automated divisions are some of the rapid thriving endorsers of EMS (Energy Management System) to allow facility, utility as well as building energy management groups.

The service, financial and automated divisions are some of the rapid thriving endorsers of EMS (Energy Management System) to allow facility, utility as well as building energy management groups.

BEMS or Building Energy Management Systems are known as desegregated, digital schemes for controlling and supervising energy-correlated building services plant and tools. The services include ventilation, heating, and HVAC or air conditioning systems, lighting or power systems of the houses and so on. The catchphrase BEMS is often operated correspondingly with Building Management Systems (BMS). Nevertheless, they are somewhat considered as the same system terminology. Independent controls for energy systems may be provided in the small buildings, however for larger or more multiplex buildings, an area with a number of buildings, or organizations with buildings located on different places- the integration of systems operation through a single connecting System extends prominent regulation and has the ability to attain compelling savings. The IEA (1997) employs the following interpretation for explaining a BEMS: **"an electrical control and monitoring system that has the ability to control monitoring points and an operator terminal."** [25]

2.2.2 Difference between BMS and BEMS:

The BEMS technology implies a comprehensive approach for controlling the building. It can also have a diverse attribute. On the other hand, the expression BEMS is confined to use for complex and progressive control systems (according to IEA, 1997). Hence, while the buildings need and have some type of control system, BEMS technology is significantly distinct form of control systems than the former one. BEMS

diverge from any other control systems mainly in the structure of communication. In BEMS, information of the processing and functions of the building can be obtained and controlled at a central, single operating point. For this reason, decisions can be taken based on the received information (IEA, 1997). This allows BEMS to optimize the system capacity. For example, the main and single operating unit can gather several information like temperature, how many people are currently in the building and from there, it has the ability to make the decision to decrease the temperature in the building where there is no one. As a result, it increases energy efficiency. Eventually it leads to cost effectiveness too [26].

Possibly the most compelling difference between BEMS and BMS is the automated control of building - electrical as well as mechanical equipment ; which is the primary aspects of BMS/BAS systems. BMS systems can turn ON/OFF, interchange settings of equipment remotely .It implies that they can control equipment by sending controlling signals without being in vicinity of the equipment.

On the other hand, Energy management software does not have these controlling characteristics yet. AS we know, BEMS has the capability to be merged with BMS system, it is moving towards supplying the tools for analysis to further study the energy patters, to find out the behavioral trends of the customer from the previous data, compare data from various time scales etc. - which are not associated with the abilities of BMS technology [27].

2.2.3 The goals of BEMS:

The goals are mainly to:

- Take part in in continuous energy monitoring.
- Ensure proper the usage of energy in the building.
- Decrease energy as well as maintenance costs.
- Protect the environment from further pollution.
- Assure energy efficiency through optimizing assets.

- Classify chances for energy preservation.
- Measure and confirm the authenticity and capabilities of energy saving activities.
- Reduce the level of carbon emissions.
- Meet the demands for energy management codes, inducements, legislation, and rules and much more.

2.3 Energy Management system overall Scenario:

2.3.1 BEMS in EU:

The European building energy management systems market is partitioned based on use of software into data management, application platform, HVAC system, asset performance optimization, and lighting system. The market is divided into wired and wireless depending on the technology. On the other hand, if we look at services, it is split into two prominent parts- support and maintenance services and consulting & training. Based on industry, it is segmented into manufacturing; communication and IT sector; municipal, educational institutions, and hospital centers; office, commercial buildings; and government [28] .

For the last five years, the EU energy management systems industry has been burgeoning at a solid rate [7]. This rate of increasing is mostly feed by the growing employment of services for smart grid. Also soaring government policies, rising competition among industrial entities, and incentives coupled with energy efficiency played a vital role in this regard. Growth is significantly high in countries, such as Germany, France, and other European countries following the increased usage of smart grid services and high the demand for products which are beneficial to environment as well as energy efficient.

The European BEMS Market is envisioned to attain USD 9.50 billion by the year of 2020, at a CAGR of 22.48 % over the speculation period from 2015 to 2020 [7].

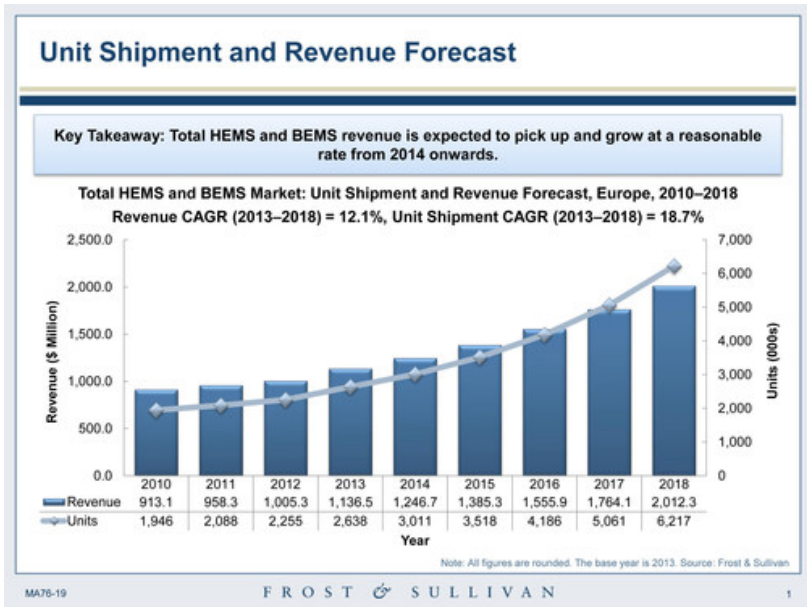


Figure 2-2: : BEMS market in EU [4]

2.3.2 BEMS in WORLD:

“Schneider Electric was the global greatest company in Building Energy Management System (BEMS) industry, with the market Share of 13 percent in 2018, followed by Siemens, Honeywell, Johnson Controls, Grid Point, General Electric, Emerson Electric, Eaton Corporation, Azbil, Cylon Controls, and Tongfang Technovator.” [10]

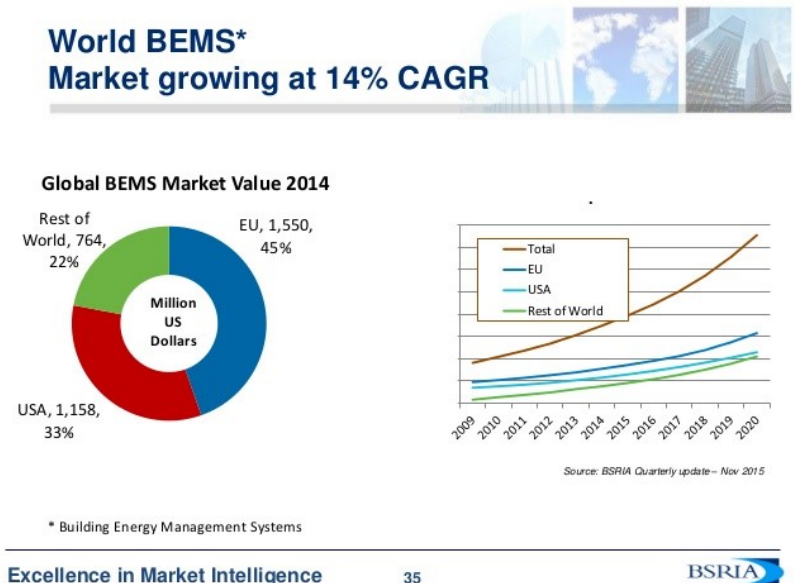


Figure 2-3: : Present scenario of BEMS in the world market [5] .

In 2019, the BEMS market proportion in the whole world was estimated as US\$ 5053.7 million, and with a CAGR of 13.3 % during 2021-2026, it is anticipated to acquire US\$ 12230 million at the end of year 2026[29].

2.4 Literature Review for the project:

A literature review is an inspection of various intellectual sources on a scholastic topic. It demonstrates a gist of up-to-date knowledge, enabling the researcher to investigate respective theories, structure, and gaps in the prevailing research.

There are two parts in our project . They are

- a) Integration of Data Reporting of BEMS ;
- b) Visualisation of the data that we have collected from the smart meter and assimilated in the server.

On present day, BEMS or building energy management system is gaining a lot of attention .A compact building normally has full controls over their own energy systems, however the picture is different for grander or complex flats, or institutions with plentiful buildings. Therefore, if the whole system can operate , controlled by a single energy management, it has the potentiality to provide superior control as well as can boost on energy savings remarkably. BEMS offers a real-time management and observation of a extensive range of affiliated systems, environmental surroundings, usage of energy, and many more.

Many scholars are enthusiastic to find out which integration system can be offer best integration with the server as well as envision the data for the users to see. So far , various projects have been carried out from multiple countries or companies.

For example , in **Guzhov.et.al.** [30] paper, the authors have analyzed the fundamental problems linking renewable energy sources with the energy saving management for the Russian economy. They have presented a new method based on the already existed model for collecting the data which includes the neural network, fuzzy logic etc .The new model describes the joined analysis and fabricating of energy consumption methodology in buildings based on big data analysis system.

To find out the contradiction, four vital problems have been inevitably solved in the paper-

a) to justify requirements of the project, which includes regulations for the authenticity of measuring sensors, locations installation and methodology for obtaining and organising the collected data.

b) the second problem was to collect these seemingly vast amounts of data, then simplify and integrate it schematically.

c) the third problem was to analyzing this data and then extracting the knowledge.

We have faced the similar problem in our project which we tried to solve by storing the data in the binary format .

d) the final problem was to confirming if the system is actually saving energy or not.

In another paper **Itoh.et.al.** [31] ,they emphasized in visualizing the energy consumption in buildings through **Building Energy Management System or BEMS** .The authors have unveiled a visualization mechanism which displays the energy consumption via BEMS. The presented tool at first separated the daily discrepancy of the energy usage and environmental measurements such as. temperature or humidity into significant number of variations.The proposed tool showed “long-term polyline chart” to portray the repetition of the daily pattern .It helps the users to simply pay attention on certain dates at distinct places. They also presented a “ one-day polyline chart” to show the day-to-day change of the documented values of the specific dates as well as places stated by click operations of the user . The paper introduced the illustrations of visualization to specify the capability of the proposed tool including an existent data-set of a office building of company.But they have encountered some problems in their findings. One of them is the authenticity of the dataset.The presented dataset for the project was not very practical as it was tested only for a small building. The result might be different for bigger buildings. This was one of the main reason for employing **Plotly** - what if we can actually see the variations of data for a larger set of data meant for a set of buildings or organisations. This problem initially inspired to employ Plotly for the said part.

A Takenaka Corporation's Machine to Machine(M2M) communications platform for building energy management system has been presented by **Yasutomo Matsuoka et.al.** [32]. Whilst traditional buildings have been exercising miscellaneous energy saving and building energy management services controlled by individual building, lately the growing development of Information and Communication Technologies (ICT) affirms expedient facilities. This can be done by employing the linkage between building energy management systems and varied smart devices, such as web applications, automotive, smart mobile phones, as well as power grid. The mentioned paper tackled with this phenomenon by applying M2M communication protocol.

A problem detection method has been discussed by **Muhammad et.al** in [33].

Smart buildings have the capacity to ensure an excellent facility for the user for supervising their energy consumption behavior. This capability can be proved a great assistant for the building energy management system or BEMS in order to find abrupt energy consumption practices.

A model has been proposed in this research to detect abnormal energy consumption patterns by reviewing the transient data streams provided by the smart meters. They explored support vector regression along with radial basis function to locate the incompatibility between the actual and predicted data of energy usage. The said model can plot the unpredictability of data and estimate how much energy consumption, the user could be anticipated.

In this initial study, they conducted the tests over an actual electrical load which suggested that the model is achievable and reasonable explanation to mitigate the problem of sudden increase in usage.

But, their proposed model has some practical problems. There was no information in the dataset for energy consumption peaks which could result in some faulty conclusion.

The sophistication and cost of each systems diversify tremendously. A company called Lucid Design Group has disclosed a "Building Dashboard Starter" package which is applicable for only two buildings. The package includes hardware and software program costing approximately under \$10,000 [34].

Energy monitoring in real-time can be considered as a successful way of supervising energy consumption and quality of power occupying a building or a chain of buildings. It guarantees a more efficient approach to consume energy by making informed decisions based on data from past and then programming it to predict future trends in consumption. **Savanna et.al** . [35] has established a Real-Time Energy Monitoring and Reporting Tool for the use of the Hal Marcus College of Science and Engineering building situated in the University of West Florida (UWF).

Their work was a combination of past projects done by two Capstone Project teams, with one team concentrating on the hardware implementation of the project for collecting the data in a database and the other focusing on the software interface for observing, monitoring and viewing the data. This project was aimed to permit the University to trail energy consumption as well as power quality in real time, analysis data from past history, and detect contrivances that can be used to legislate energy usage and power quality of the user.

The visualization and reporting software was implemented in **Python**, a **MYSQL** database for storing data, and can be cooperated side by side with a independently developed hardware interface. The software is embedded in a hardware interface that utilizes an IoT based sensors to calculate data from Buildings where it was being used. Voltage, current, power, frequency, etc. values were attained from the sensors and then kept in a database. The data was displayed in a user defined graphical and tabular outputs.

The primary advantages of the proposed project were:

- high accuracy readings,
- opportunities for improving cost ;
- growth of efficiency,
- having the capacity to monitor loads to identify signatures and potential issues.

This implementation can be taken as a basis for more research and development in future.

The proposed energy monitoring and reporting software now has been implemented in the central data center situated in the Department of Electrical and Computer Engineering of the said university.

In another article , [36], Shen et al. ; proffered an **information centric collaborative Fog or ICCF platform**, empowered by a novel horizontal Fog-to-Fog layer for the purpose of constructing large-scale Internet of Things (IoT) networks in near future.

ICCF aids sensor data processing performance by enlivening horizontal data transfer in the Fog layer via wireless name-based Fog-to-Fog data transmission. It uses the Fog node's distributed data processing power to attain a copasetic data processing performance, while communication with the Cloud is only necessary to report possible anomalies.

However, due to the connection-less nature of this system , it can exceptionally decrease data connection overhead. The proposed model stipulates real-time communication and the capacity to endeavor large-scale IoT data.

Building energy management system (BEMS) for detecting abnormal sensor data was considered as a case study to elucidate the proposed design philosophy and, furthermore, to ensure the benefits of the proposed ICCF by doing a variety of experiments based on the sensor data collected from a real-world indoor environment.

Analysis of Variance (ANOVA) system was suggested by Bohari et al [37] to analyze the reduction of energy consumption.

They have proposed significant reduction on the impact of climate change via energy management via this model. In this project, lighting system in UTeM's library is underlined.

The goal of this research was set as-

- To investigate the energy demand and define the possibility of the facets of energy saving by optimizing current lighting system.
- To collect data then used to investigate and analyze total power consumption

in the building .

- And finally analyze the saving by using ANOVA method to validate the method

They have suggested **ANOVA** to improve the energy consumption of user and as a means of reporting method; on the other hand; the MATLAB and EXCEL were employed for analyzing the data and ascertained to understand the technique and flow of the software.

Their project has proved that ANOVA method can be utilized as an appropriate approach to analyze energy saving with more accurate and simple procedure.

Chapter 3

Structure of the Project

3.1 Brief Discussion of the project:

The resolution in this thesis is to collect values presented by the previous existing project; project them through database management system, and finally plot the consumption rate of the system in a line chart.

Furthermore, as mentioned in **chapter 1**, we aim to plot parameters such as current, voltage and power factor of the system so we can observe if they can help us to explore whether it can be related to the consumption rate of the user.

To obtain this goal, the structure of the project has been divaricated into three cardinal segments. They can be manifested as follows :

1. Smart Meters ;
2. Server/Back End;
3. Client/ front end.

In order to accomplish the correspondence between the whole system, two paradigms of communication protocol have been implemented in this project. One of them is between the meter and the server which can be recognised as the **MODBUS TCP**; while the other is between server and client. It can be delineated as **HTTP Requests**.

MODBUS communication can be administered through **TCP/IP** protocol or **Serial port** [38]. However, **MODBUS TCP/IP** has been selected in this project to

Structure of The Project

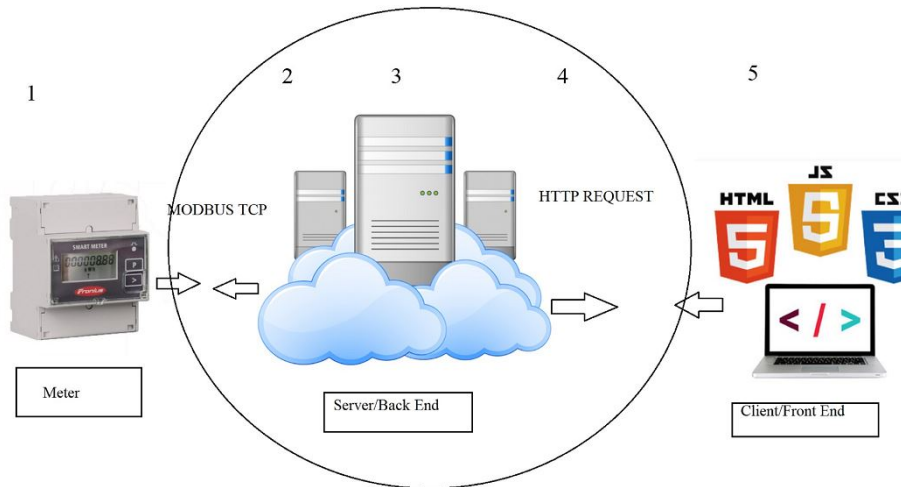


Figure 3-1: The framework Of the Project .

interlink smart meter to server.

Http protocols has been designated in order to conduct the dialogue between Server/back end and Client/front end. Clients and servers interact with each other by interchanging independent messages [39]. The messages commissioned by the client, typically a Web browser, are known as **requests**, while the data dispatched by the server in form of an answer are dubbed as **responses**.

3.2 Smart Meter:

Smart Meter is that electric device which registers how much electric power is used over a period and conveys that data to a control station for monitoring. Later the information is exploited for the purpose of management and charging. Smart Meters have the competency for bilateral communication i.e., it can interact between the central control system and the meter. Real-time sensors presents information regarding power surges and outages.

The big difference with a conventional meter is that the smart meter may be a device that enables the user full control over how to manage all

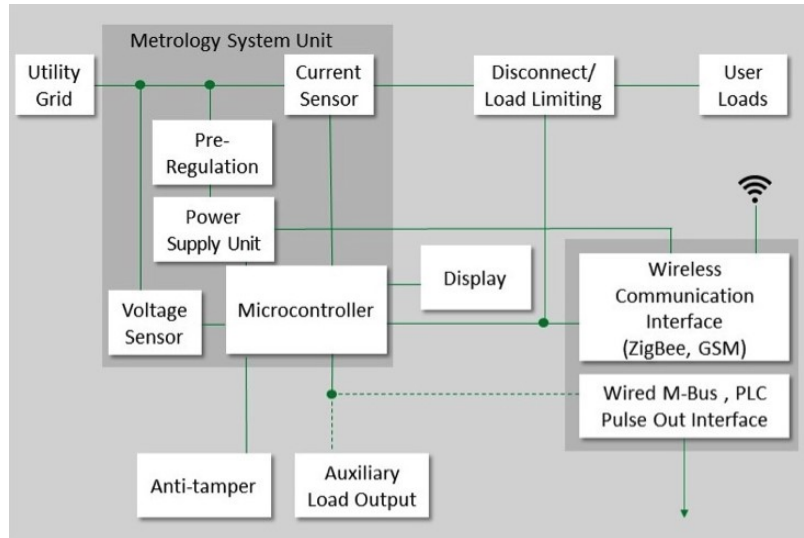


Figure 3-2: Block Diagram of a typical Smart meter [6].

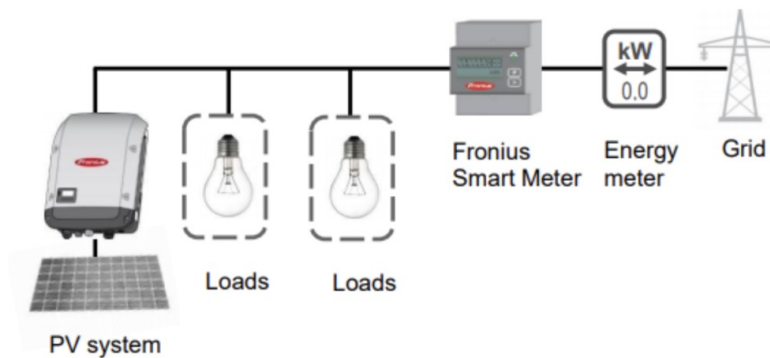


Figure 3-3: Connection of Smart Meter with Grid and Loads [7].

the knowledge regarding consumption regardless of time, automatically and also remotely. That is to say, customers can supervise their energy consumption fully. Smart meters can also mitigate all possible interference or errors that can hinder traditional measurement system [40].

3.3 Advantages and Disadvantages :

There are numerous advantages and a very few disadvantages of Smart Meter. Some of them are listed below:

Advantages :

There are numerous advantages :

a) Smart meters spontaneously supplies data to the main control office instead of customers submitting them to the office [41].

b) From the In-Home Display, users can easily explore their consumption of energy associated with the cost. It inspires customers to use their energy in a cost effective way [41].

c) Electric companies has the ability to enable dynamic pricing [41].

d) With the traditional standard meter which is not smart- the supplier will send out the bill to the customers on the basis of the estimation of energy usage of users over the billing period. Sometimes the readings might be controversial if the supplier cannot accurately calculate the exact consumption of the customer[41].

With a smart meter, the chances of getting inaccurate shocking bills are next to zero.

e) Electric companies can skip out on having the capital expense of constructing a brand new power plant [41] .

f) As the In-Home Display shows how much energy is being consumed at a given period of time, users can easily identify if there is any sudden surge of power due to a faulty equipment. Therefore, it helps them to take care of the faults timely and safely before anything hazardous happens[42].

g) Smart meters encourages customers for healthy energy consumption through buying suitable energy saving appliances so that there is less environment pollution as well as decrease pressure on the grid. Smart Energy GB predicts a 24% decrease in pollution's from homes appliances and businesses facilities by 2030 [41].

h) It is paper friendly system as everything is done online [42].

i) Electric companies can delete manual meter readings after they are done with the monthly so that it doesn't overload the system [42].

Disadvantages :

Though there are many advantages, there are some disadvantages also :

a) Smart meters have some cyber-security concerns. There is a possibility that these could be hacked from outside. As it is connected online, hackers could disrupt the whole electricity system. Anderson and Fuloria warned us in an article stating we should be careful about smart meters regarding the security problems [43].

Kerb [44], who is a security expert; also reported that in Puerto Rico after smart meters have been installed, the FBI encountered a substantial amount of possible cases for electricity theft [44]. So it's safe to say that there are some concern regarding security with Smart Devices.

b) The installation fees of these meters are quite extravagant as it uses state of the art sensor networks. Therefore, often the companies may face some difficulties to convince general public to use it because of the high installation cost [41].

c) There are some uncertainties regarding the microwave radio frequency transmission from Smart Meters [45].

d) It could be overwhelming for the general people to understand all the electrical jargon of the Smart Meters [41].

3.4 Types of Smart Meter Used in Thesis :

There are 4 types of Smart meter have been used in the project . They are :

a) CVMk2:

CVMK2 is manufactured by **Circutor** [8]. It has the ability to measure and displays electric parameters both in the balanced and unbalanced ways [8] .

True RMS values are calculated through three alternating voltage inputs, two voltage references- neutral and ground. There are four current inputs to measure secondary which are connected with the outside current transformers. They have programmable measuring instrument for network and power supply quality analyzer .It proves a vast selection of uses which is evident in the configuration menus [8].

CVMk2 has a backlit 1/4 VGA graphical display for reading the electrical measurements. Designated keys are assigned for showing Real time, maximum or minimum values of parameters [8].

Internal processor has the ability to process over 500 electric parameters through communication as well as the display screen. Those parameters may be supplied through a single or three phase system [8].

PM 710 is a product from series of **Power Logic 700 series of Schneider Electric** [9] . The difference between the original PM 700 and PM710 is that later has added **MODBUS communication**. It can be flash mounted and is suitable for indoor installation. Maximum power consumption rate in VA is 5VA and can operate between 45 to 65 Hz frequency ranges. The display type is Backlit LCD [9].

c) **CEM C20 :**

CEM C20 was first manufactured by **Circutor** [46]. It's a three phase electrical energy meter which can directly measure up to 65A. It has a built in LCD display with a rotating 7 digits screen system. For installing communicating Module (CEM-M), it has a feature for optical communication port [10].

Key Applications-

a) It can sent energy consumption report to a remote system through PLC/BMS [10].

b) Can provide cost control features in industrial processes for achieving a high consumption/unit ratio[10].

c) Can display values of electrical parameters in single phase or in 3 phase [10].

d) **PAC 4200:**

PAC 4200 is developed by **SIEMENS** [47] . In industrial, commercial or government applications, where some form of metering I/O or logging is necessary, power monitoring device the **SENTRON PAC4200** could be really suitable. The meter has the ability to be used either as a standalone or as a part of an automated monitoring system. Advanced power quality monitoring and logging features varies from

sub-billing or cost allocation infusions with multiple tariffs, single low voltage breaker / building metering to sub-station main feeder monitoring. The SENTRON PAC4200 supplies open communication channel using the standard **built-in Ethernet Modbus TCP system**. For easy transformation into any local or remote monitoring system, there is also an Optional **Modbus RTU or PROFIBUS-DP protocols** [11] .

3.5 Server:

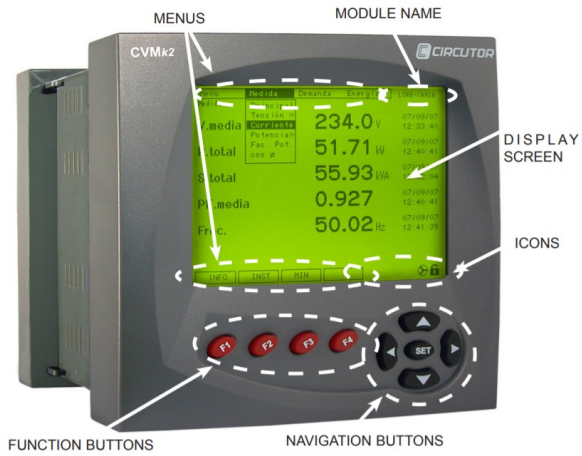
Server is the connecting computer programs that enables various programs to be connected with clients. This architecture is known as the client–server model. Servers can provide various tasks, often named as ”services”, which includes allocation of data or resources among several clients, or operating program for computation/visualization on the basis of request of a client. Server can have several clients and similarly a client has the ability to process multiple server. Types of some typical servers are database servers, mail servers, web servers, file servers, game servers, print servers, as well as application servers [48].

The relation between server and client is often performed by the request–response model- the most popular form. In this application, the client sends a request to the server and in return, server responses back and performs some actions [48].

3.5.1 Server in the thesis :

In the current Master Thesis Project, the communication protocol used to link the server with the **DAU is MODBUS protocol**. After reading the values from the meters, the server performs a validation and scaling of the magnitudes; Then it prepares the information in order to send it to a given database, to store the data in binary format. In the server -Read, prepare, write- each one is done in 1 sec time. The time duration for executing each operation - read, prepare , write ; is confined to only 1 sec.

Structure of the main database is SQLite database – where the users and devices



(a)



(b)



(d)



(c)

Figure 3-4: a) Simple diagram of CVMk2 (Frontal View) [8], b) PM 710 [9], c) CEM C20 [10], d) PAC 4200 [11]

Client-Server Model

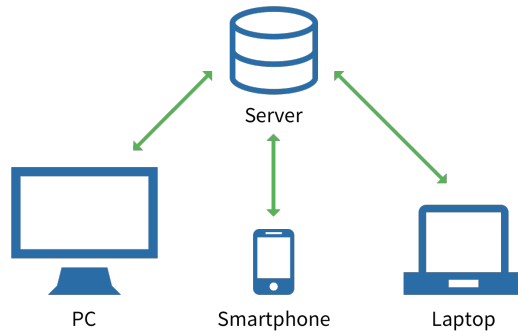


Figure 3-5: Server Structure [12] .

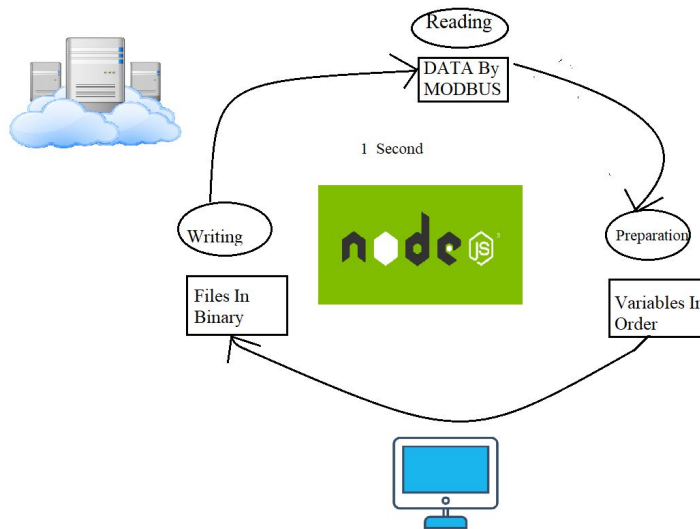


Figure 3-6: Structure of Server in the thesis.

are saved. Why we chose the binary format and to choose the database in folder – it is done to make it faster. As the number of saved data's are huge we have to think about time series database for future – such as influx dB/ grid dB, which can be a great project for future work. Another alternative that we choose in our system that we saved them separately – original in binary.

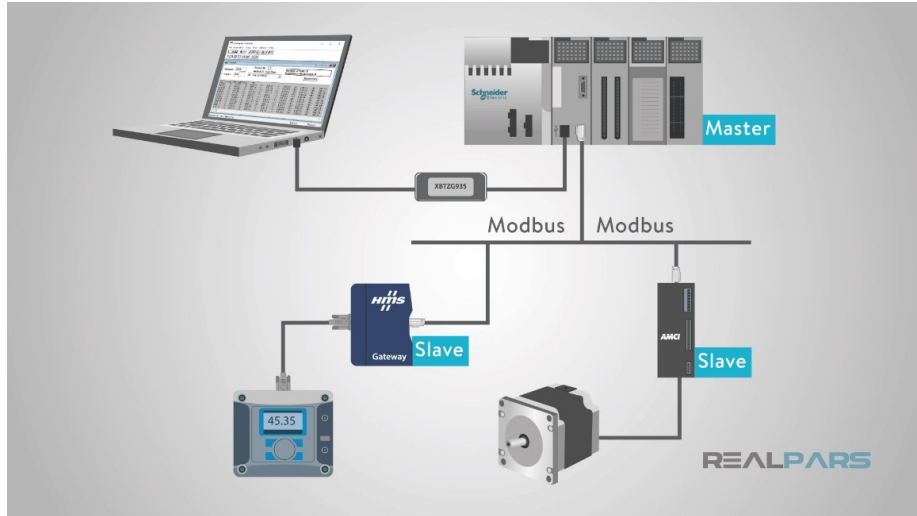


Figure 3-7: Block-diagram for MODBUS System [13] .

3.5.2 What is MODBUS:

Modbus is a communication protocol which was first developed by Modicon systems in 1979 [49] . Simply we can say that it is a method used for dispatching information between electronic devices through serial lines. Modbus is the popular method for communication protocol in Industry sectors for the purpose of conveying Operational Data (OD) as it is royalty-free. Modbus uses serial (RTU) and Ethernet communications (TCP/IP) for communication purposes. The architecture of the system is based on Client-Server architecture. The device requesting the information is typically known as the Modbus Master and on the other hand, the devices providing the information are called as Modbus Slaves. For a typical Modbus network, only one Master is appointed but the number of slaves can be increased up to 247. Every slave will have a unique Slave Address from 1 to 247 in the system. The Master also has the ability to write information to the Slaves[49] .

3.5.3 Application of MODBUS Protocol:

There are numerous applications for MODBUS protocol. As it is a seemingly free communication protocol, not only industries but also plenty of organizations are using it. Some of them are mentioned below [38]:

a) In factories, where wireless communication is necessary, Modbus is a perfect protocol for RTU applications.

b) It has been employed in countless gas and oil and substation applications for communication purpose.

c) The semiconductor industry has implemented Modbus TCP/IP in their communication protocol on the basis of customer request. This enables SEMI Sensor Bus compatible sensors to interact with each other via Modbus TCP/IP.

d) It is not only for industrial purposes but also Building , houses as well as energy applications uses this protocol for their benefits.

e) To check the temperature for a single surface, MODBUS can be useful for the hospitals' IT department.

f) Modbus TCP transactions can easily detect traffic jam in the roads by cross-examining with normal traffic behavior.

3.5.4 MODBUS data type:

There are various data types for MODBUS communication system. They can be addressed in a read or write request in the system. Different types of MODBUS data is listed in Table 4.1.

| Serial No. | Data Type | Description |
|------------|------------------|-----------------------------|
| 1 | Coil | A writable single bit |
| 2 | Discrete Input | A read only single bit |
| 3 | Holding Register | A writeable 16 bit register |
| 4 | Input Register | A read only 16 bit register |

Table 3.1: MODBUS data types [21]

For our project we used MODBUS TCP for the communication purpose between the server and the back –end.

3.5.5 MODBUS TCP/IP Protocol:

TCP/IP is considered as one the frequent transport protocol for the Internet. It is famous for ensuring safe and reliable data transmission between machines due to its layered protocols. Therefore, Ethernet has become the de facto communication protocol in the corporate enterprise organizations. It is also known as one of the cost effective systems. Linking Ethernet- an adaptable, multifaceted, and universal physical network with TCP/IP- a ubiquitous networking standard and a vendor-neutral data embodiment, Modbus provides a truly open, accessible network to everyone to interchange data. It is easy to implement in any device which has support system for TCP/IP sockets [50] .

3.6 Database Management System:

DBMS or database management system is a widespread software system which is adjusted to interpret, control, manage, and retrieve data located in a database. It usually exploits the data itself, its format, field names, also structure of record and

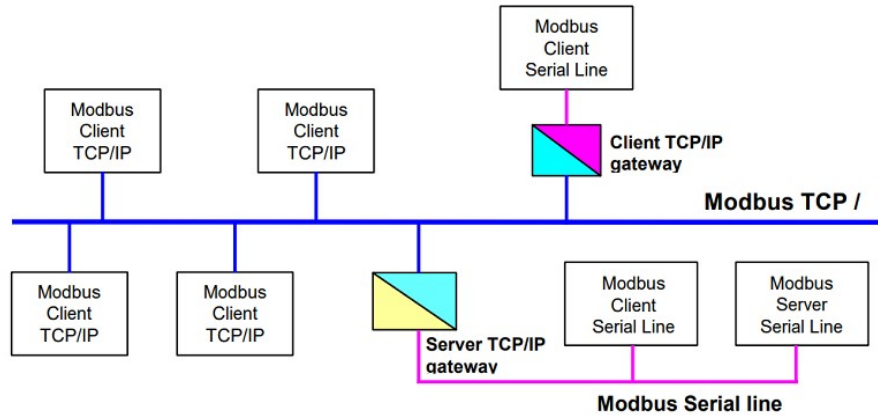


Figure 3-8: Simple Structure for MODBUS TCP [14] .

file. It has the ability to employ rules to authenticate and manipulate this data as well. In a simple term, Management here clarifies that we can perform any necessities related to table like add, delete or modify data. In a nutshell, it is a user-friendly software that allows us to perform all operations related to any common database [51] . Database management systems are built on definite concepts for data handling, as the custom of allocating a database develops. The past databases only dealt with individual single pieces of data which were formatted specially. However, modern systems are much more evolved and they are designed to handle all kinds of data even if some of them are less formatted.

Now a days, DBMS has various functions that permit management of a database and data. The data which can be divided into four main functional groups are stated below [51]:

- Data definition: Create, add, delete or edit the definitions of the organization of the data.
- Update: Inclusion, alteration, and removal of the real data.
- Restitution: To render information in such a way that it can be directly usable or it can be up for additional processing by different applications. The recovered data may be made feasible in a somewhat same form in the database or in a complete new form achieved by altering or connecting available data from the

database.

- Administration :Enlisting and supervising users and performance, applying data security, fostering data integrity, dealing with concurrency control, and recovering information that has been damaged by some system failure.

3.6.1 Types of DBMS [1]:

There are principle four types of DBMs. They are following:

- a) Hierarchical database;
- b) Network database;
- c) Relational database;
- d) Object-Oriented database.

For the Master’s Thesis, we used SQLite database management system for storing files of users and devices. SQLite is one kind of relational database management system.

3.6.2 SQLite database management system :

SQLite is one of a kind software library which is a type of RDBMS or a relational database management system. **The lite in SQLite stands for lightweight in respect of configuration, database management, and mandatory resources.** The code for SQLite is in the domain for public use and therefore, anybody can use it for free for any project- be it commercial or personal. SQLite is the most popular adopted database in the world with seemingly uncountable applications, including various high-profile schemes.

3.6.3 Why we used SQLite in our project: [2]:

SQLite uses dynamic types for creating tables. It allows the user to store any value in any column, irrespective of the data type [52].

- It can create in-memory databases that are very swift to work with.

- By connecting to a single database we can access to several database files at the same time through SQLite. This allows us to have options for delightful privileges including joining tables in various databases or copying data between databases through only one command.
- Another important points to use SQLite is that it is fast. Often, it is faster than direct file system I/O.

SQLite has the following significant features which are noted below:

a) No Need for Server:

Usually, a separate server system is required for RDMS such as PostgreSQL , MySQL etc. to function properly. These applications use TCP/IP protocol for accessing the database server in order to send and receive requests. The structure is known as client/server framework. However, SQLite does not operate this way. It does not need any server to run. SQLite database is combined with the software that can access the database. The program interacts with the SQLite database, can read and write directly from the database files kept in the disk [53].

b) Self-Contained

It is a self-contained system, meaning it needs trifling support either from the running system or any exterior library. ANSI-C has been used to develop SQLite. This makes SQLite available in any system especially in different embedded devices such as Android phones, iPhones, portable media players, game consoles, etc [54].

c) Transactional:

Every transactions in SQLite are said to be Atomic, Consistent, Isolated, as well as Durable. In other words, all queries and changes are completely ACID-compliant.

d) No Configuration Needed :

As SQLite doesn't require server to operate, we don't have to install it to use. It has no server process that needs to be set up, started, or aborted. Moreover, it does not require any configuration files .

3.6.4 Binary Database :

For storing data of the meters in our project, we used Binary Database .

Why Binary database was implemented in this thesis:

The reason behind choosing binary database:

- It was faster than other database for sorting data for meters.
- The memory is less complicated and light compared to SQLite decimal or SQLite integer.

| Parameters | Binary | CSV | SQLite(decimals) | SQLite (integer) |
|--------------|--------|------|------------------|------------------|
| 1 Day(MB) | 8.3 | 13.5 | 19.7 | 8.4 |
| 1 Month (MB) | 249 | 405 | 591 | 252 |
| 1 Year (GB) | 3 | 4.75 | 7 | 3 |

Table 3.2: Size Comparisons for storing data of meters

| Parameters | Binary | SQLite (integer) |
|-------------------------|---------|------------------|
| 60 moments (one by one) | 0.003 s | 10.814 s |
| 1 day (once) | 1.687 s | 1.613 s |

Table 3.3: Data write Speed

3.7 Client / Front end :

3.7.1 HTTP Requests:

HTTP stands for Hyper Text Transfer Protocol. When the client types the URL of the website in any browser, they don't get connected instantly. At first computer makes the physical connection between the client and server with the help of internet. Internet uses the TCP/IP protocol via cable or wireless media to establish this connection between client and server and therefore, sets the environment for the two computer to be connected using the HTTP protocol. After the connection is established, the client sends a HTTP message in the form of request and waits for the server to respond. Then the server process the requests, prepare the response and send the client as a response to the requests.

To its central, HTTP Request can be considered as a packet of binary data directed to server by the Client. HTTP assigns different kinds of request methods to demonstrate the appropriate action to be executed for a specified resource.

HTTP Request consists of the following main parts:

- a)An optional Body of the Request;
- b)Request Line;
- c)Headers, 0 or more Headers in the request.

There are different kinds of HTTP requests, such us :

***GET:**

The GET method demands an exhibition of the definite resource. Requests using GET should only be confined to getting data.

*** HEAD:**

The HEAD method looks for a reply similar to that of a GET request, but there is no the response body.

* **POST:**

The POST method is employed for submitting an entity to the specific resource, therefore, often resulting a change in state or the side effects for the server.

* **PUT:**

The PUT method switches all present models of the target assets with the request payload.

* **DELETE:**

The DELETE method deletes a certain resource.

In the front end of our project, we need some users to be registered so that they can add, edit or delete any device from the server. To make a communication between the front end –user side and the back end of the server side, we need a communication protocol between them – HTTP protocol plays a vital role in this regards.

3.7.2 Request categories:

In our project, we have five types of request, which are related to:

a) Session :

- It is basically log in / log out ,.
- Deals with different types of User profiles: Owner, Administrator, Engineer, Viewer.

b) User management:

Deals with Add, delete and modify users.

c) Device Management:

Deals with Add, delete, modify and disable devices.

d) Data History:

Consult historical data of a specific meter for a certain period of time

e) Real-time data:

Can verify real-time data from the meters.

3.7.3 . Profile of the Users:

Server stores information about profiles for the users to use in the database. These users have access to applications connected to the system depending on their profile level. User profiles consists of valuable information about the users like name, id, IP address and others information. Server bestows a variety of mechanism to help the users to manage their profiles such as the Management level. On the basis of their level, certain users can add, edit, search, view, and delete users/devices or data etc.

For operating the session, we have some user profiles in our project. They are:

- a) Owner;
- b) Administrator;
- c) Engineer;
- d) Visitor.

3.7.4 Data History:

Data history in for a Smart Meter, in a broad sense, is a collection of data about past events and circumstances pertaining to a particular meter or user etc. By definition, historical data includes most data generated either manually or automatically within a certain period of time - it can be an hour, a day, and a month or even for years [55].

The importance of analyzing the data history of a Smart Meter :

- a) It helps the companies to understand the volatility of users through their hourly consumption [56].

b) It represents the typical daily habits of consumers by obtaining consumption records that occur at different times of different day [56].

c) It helps the user to predict energy cost of the month or even for a year as they can read their past data from the smart meter [56].

d) It enables the companies to find similar consumers by running times series similarity search of their past data [56].

e) It helps them to detect anomalies cause if there is any faulty equipment, a huge power surge will show for a certain period of time [56].

3.7.5 How data history is presented in the project:

In our project, the data is kept stored in a different way. It can be stored as a daily basis, monthly basis or even as a yearly basis. The below table shows what types of resolutions are taken regarding the data history and how many times they are being sampled:

If the user asks for a data for a specific day, the meter will give him the result in a minutes or any specific hour of the day, it will be in seconds. If the consumer asks for a data of the past month, the result will be shown in hours. Meanwhile if the required data is less than 5 years old, the resolution will be in days. On the other hand, if it's more than 5 years, it will be given as no of months.

3.7.6 Real time data of Smart meter :

Real time data means when the data is presented instantaneously for a specific time. Real time data in smart meter plays vital role in many aspects . Some of them are

a) We can easily supervise if we are wasting too much energy or not as we can see the value on a real time [57].

b) As the companies can monitor the real time data, they can take necessary safety measures if there is any sudden power outage or surge due to faulty equipment's [57].

Chapter 4

Necessary tool of the Project

4.1 Node.js :

Node.js is a cross-platform length domain and records for operating JavaScript applications anywhere apart from inside the browser .It is a server-side base which was fabricated on JavaScript Engine (V8 Engine) of Google Chrome. It was developed in 2009 by Ryan Dahl and its up-to-date edition is v0.10.36 [15]. The definition of Node.js given by the official documentation is that “Node.js is a platform built on Chrome’s JavaScript runtime for easily building fast and scalable network applications. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient, perfect for data-intensive real-time applications that run across distributed devices.” [58] Node.js is known for setting up server-side as well as networking web applications. The source is free and therefore, anyone can use it for their purpose. It can be directly downloaded from their official page without any cost. It has an ample library of different JavaScript modules in order to facilitate the general growth of the numerous web applications.

4.1.1 Characteristics of Node.js :

The bellow list has some of the principle features of Node.js that enables it become of the popular choices for software engineer:

- Very fast: As it was executed based on Google Chrome's V8 JavaScript Engine, therefore, it has a library which is extremely fast in executing codes.
- No buffering: In case of uploading audio or video files; the overall processing time is less in Node.js. These applications easily results the data in chunks, hence, in Node.js, there exists no buffering in terms of data.

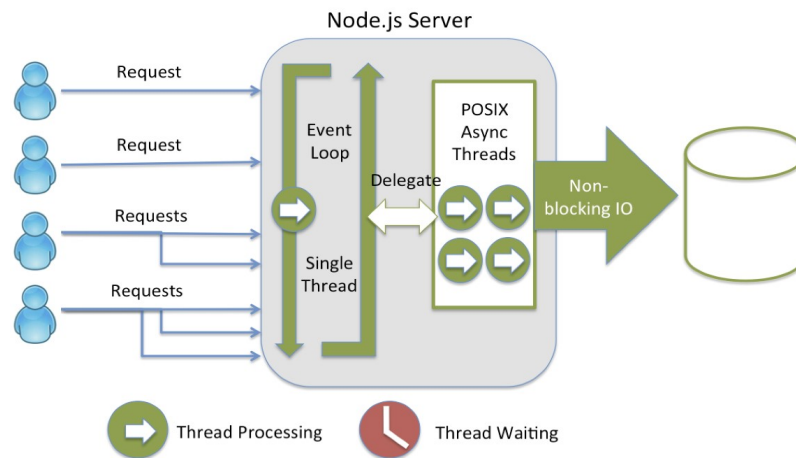


Figure 4-1: Operation of Node.js Sever [15] .

- Asynchronous I/O and Event Driven: All APIs of Node.js library are non-blocking i.e. asynchronous .Ergo, its server doesn't need to wait for an API for returning data. After calling the first API, it moves on to the next one and a notification mechanism of Events of Node.js assists the server to acquire a reply from the first API call. It is one of the reasons why it is fast in operation.
- Model of sole threaded: Node.js fulfils a single threaded prototype followed by event looping.
- Free and Open source: Node.js has a source community which is open and free. Due to its nature, it has been responsible for creating various outstanding modules. These add extra capabilities for the applications of Node.js.
- It permits a user to employ the same language at front end or at the back-end. With the same language, the cost will be less. Therefore, it is a cost-effective tool.

- As it is very swift, so performance rate will be also increased and even it has enhanced JavaScript.
- It is very user friendly especially for a beginner and having only basic knowledge of JavaScript. It is possible to learn to operate Node.js with few efforts and can be suitable for any types of web development projects .
- The chat-based app development needs easier faster, simpler and more systematic advancement and formation of the app. The Node.js and .npm are both open source software which are perfect for chat based applications.

4.1.2 Application of Node.js :

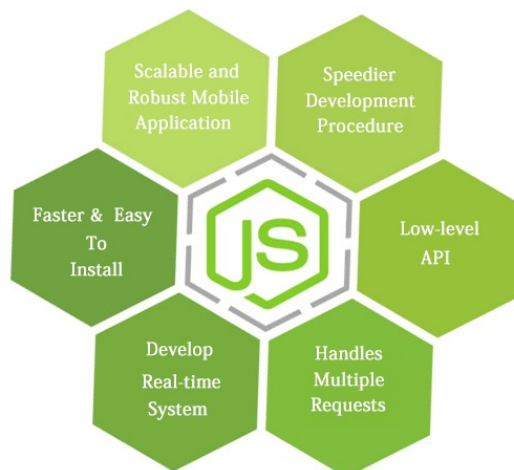


Figure 4-2: application of Node.js [16] .

There are many fields where Node.js can be used. The following fields are quite notable:

- Applications linked to I/O;
- DIRT or Data Intensive Real-time Applications;
- Single Page application software;
- Data streaming programs;
- Applications meant for JSON APIs.

4.1.3 Administrating Node.js in The Project:

In this thesis, the results; after compilation; were obtained using Node.js platform supported by JavaScript.

Comparison of Node.js with others:

- Node.js is known as a less complicated web framework than its competitors like **Django or PHP**. Django is very complex to deal with as the web developer has to go through a strictly specified route for solving problems but for Node.js- the developer can follow his own rule for the said purpose [59].
- Several years ago, PHP was considered best when it comes to solving backend setbacks but since Node.js has began entering server-side sphere, it has successfully shifted the backend programmers from traditional PHP due to its flexible nature and indisputable structure [60].

4.2 Express.js :

4.2.1 Introduction to Express.js :

Express is a variety of Node.js web application. It has nominal and flexible configuration which is responsible for a robust package of attributes. They are dedicated for web as well as mobile applications. It has been known as the de facto conventional server configuration devoted for Node.js. It familiarizes the mechanism of advancement by presenting a set of convenient packages, features, tools, and plugins [61].

4.2.2 Applications :

Express.js is perfect to be used for [62]:

- a) Real-time operations;
- b) Applications used for Visitor monitoring;
- c) Applications that work with third party resources.

4.2.3 Pros and Cons of Express.js:

Pros:

Many web developers prefer Express.js development due to its simplicity, flexibility, performance and extensibility. Main advantages are stated below:

a) **App development is swift:** Its structure gives the user an opportunity to apply the identical JavaScript language for both the back-end and front-end applications. It gives JavaScript developers the opportunity to transfer into full-stack. As a consequence, the development process becomes faster and simpler as only a single person can be able to control both demonstration and data access layer.[62]

b) **Handling of I/O request:** Among the applications that are responsible for managing a good deal of requests and notifications from the users, Express is considered one of the best in this kind. This is exactly one of the pivotal reasons why Uber has chosen Node.js. [62] In conclusion, Node.js integrated with Express.js has the ability for supporting thousands of compatible actions.

c) **Cost effective system in case of hiring development team:** It minimizes the procedure of introducing mobile apps and increases the efficiency. Same language can be used to develop the server along with mobile app [62].

d) **Community is based on open -source:** Express.js is one of the most famous among Node.js frameworks. Due to nature of the open-source community, the code is continuously reviewed and upgraded. The originator of the Express.js, TJ Holowaychuk, declared: “There is no way I could have learned everything that I have without open-source. Contributions and feedback you get on your own code are really helpful. Naturally it feels great to have people enjoy something you have created as well, so that can be fun”. [62]

e) **Integration is straightforward for middleware as well as for third-party services :** It is an open-minded framework, which implies that there is no strict and fixed rules on dealing with specific tasks or what components to use any middleware can be employed in the order according to the convenience of the user. Moreover, user has the freedom to design their own app, as there is no fixed way for

doing it [62].

f) **Express.js can be learned easily:** Most developers prefer Express.js because of its easy to learn framework. It is widely-documented and provided with bigger community [62].

g) **Popularity :** When it comes to choosing one feature from others; which are based on NodeJS frameworks, Express owns foremost position on popularity amidst computer engineers without any doubt. Various widespread infrastructures such as **Hapi, Locomotive, Flatiron, Total.js** and others fall far behind the leader [63].

Cons:

Although Express.js is a very simple and user-friendly framework for using, it has few minor demerits that may interrupt the development process. Here some of the pivotal problems are discussed below:

a) One of the biggest flip sides for Express.js is called '**Callback hell**' problem, which has the capacity to entangle the entire structure of the code after several callbacks. As a result, the whole callback process becomes impossible to maintain in the future [62].

b) Middleware is a fragment of chained operations that function between the client request and the server answer. This setting sometimes can be difficult to apprehend [62].

c) It is not recommended for larger projects [62].

d) In the event of developing software from scratch, **Koa** and **Hapi** are proved to be more dynamic and apposite than Express.js [5].

4.2.4 Application of Express.js in our project :

- **Express.js was implemented in our project due to its popularity as one of the most basic frameworks for developing *Node.js* platform.** It prevents us from writing the same code more than one time [64] .
- Node.js is an I/O mechanism whereas an HTTP module is included. If we have only included an HTTP module in our project, plenty of tasks such as parsing

the payload, cookies, accumulating sessions, electing the best route pattern based on standard expressions would have to be re-executed every time. **With Express.js, we have successfully bypassed this complication .**

Comparison of Express.js with other:

Express.js is still considered to be the best when it comes to establishing structure for Node.js other than **Redis or MongoDB, Ruby Sinatra or Ruby on Rails** [65]. Express was distinctively influenced by *Sinatra*. It's much faster and takes less time to compile.

4.3 Angular:

4.3.1 Introduction to Angular :

AngularJS is a web application which has an open-source framework. It was initially designed by Misko Hevery and Adam Abrons in 2009 [66]. According to the official documentation -" **AngularJS is a structural framework for dynamic web applications. It lets you use HTML as your template language and lets you extend HTML's syntax to express your application components clearly and succinctly. Its data binding and dependency injection eliminate much of the code you currently have to write. And it all happens within the browser, making it an ideal partner with any server technology.**" [67] It is presently managed by Google. The current version is 1.2.21 [66].

Every Angular consists of a root module, commonly named as **AppModule** [68]. The module offers the bootstrap components that activates the application. An app usually comprises several functional modules. Similar to **JavaScript modules, NgModules** has the ability to transfer functionality from different **NgModules**. They also permit their own functionality to be circulated and used by other **NgModules**. For an instance, user has to import Router **NgModule** if he wants to apply router service in his app [68].

4.3.2 Features of AngularJs:

There are various features of AngularJs . Some of them are stated below :

a) It is not browser specific application: Other than internet explorer 8.0, it is active on all major browser. Moreover, it can even run on Android based smartphones as well as IOs based phones/tablets [69].

b) It has less code: Due to its code-less nature, a programmer can write less and be able to execute more functionality with the same code [70].

c) Productivity: The user interface is very simple to operate and due to robust template syntax, it is also very fast [70].

d) Performance and Speed: Because of code splitting, angular apps code loads quickly. Therefore, they are very fast and efficient performer [70].

e) Deep Coupling: It allows users to bookmark any web page. Hence, they don't have to change their state, as the page gets saved by its URL [70].

f) Dependency Injection: Angular has a built-in injection which provides assistance in developing the application easily so that it can be understood for the beginner [70].

g) Routing: The application of routing allows to users the opportunities to switch between views [70].

4.3.3 Pros and Cons :

Pros:

List of some advantages are stated below :

- Has the feature of easy extension [71];
- Open source [71];
- User can test it easily [71];
- Great MVC [71];
- Angular is supported by Google[71];

- Anyone can learn this language easily .No Pre-requisite knowledge is required[71];
- Single page application (SPA)[71];
- Easy to customize[71].

Cons :

There are few cons :

- Angular doesn't have any server authorization or authentication facilities. Therefore, its less secure than any other web application [71].
- There is no specific way to complete a task so it can be overwhelming for a user to anticipate which best possible way to take to accomplish a certain task [71].
- It's a vast and complex language [71].
- AngularJs is solely dependent on JavaScript. If these scripts will be hidden for some reason, the resultant pages will be seen as a basic page [71].
- As it depends on JavaScript, there is an issue of Memory leakage in JS which can be a problematic for Angular [71].
- AngularJs isn't supported by Internet Explorer 8.0 [71].

4.3.4 The motive behind instituting Angular for this project:

The principle reason for choosing Angular.js for our project because it enables us a two-way data binding communication process whereas it can automatically fetch information about any changes made in the JavaScript on UI for users to interpret; while the directives permit to create separated and reusable code.

Comparison of Angular with other:

There are other tools for the same purpose as Angular.js , such as **Vue.js**, **Aurelia**, **Polymar** etc. But still Angular.js is considered to the supreme when it comes to two way binding communication [72].

4.4 Postman :

4.4.1 Introduction to Postman Tool:

Postman is an application programming interface or in short- API development tool. It is programmed to create, test and revise those APIs. Approximately any support or performance that are rudimentary for any developing program is encapsulated in Postman tool. Almost every month, more than 5 million developers use this tool to implement their API development with ease and without any complexity. **Mandy Whaley**, Senior Director of Developer Experience, from Cisco DevNet said **”Postman Collections give our users an easy path to gaining basic API skills or a quick on-ramp to new Cisco APIs and features.”** [73] Another example can be **Marcus Nance**, Delivery Lead, Movember exclaimed that **“We use Postman to make sure our APIs’ performance is within tolerance. It’s more efficient, less expensive, and gives us confidence as we transition over to a new framework.”** [73]

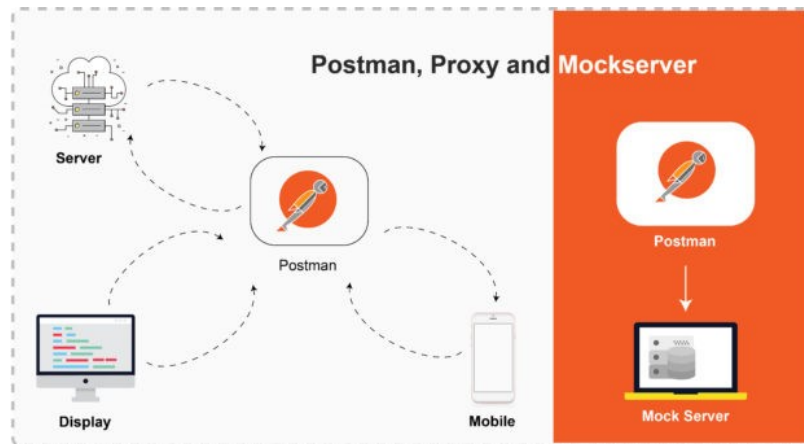


Figure 4-3: : Applications of Postman [17] .

It is highly capable for:

- Initiating different HTTP requests such as -GET, POST, PUT, PATCH etc,
- Preserving environments in such a way that it can be brought back for later use,

- Altering the API to code for several other languages, i.e., Python or JavaScript.

4.4.2 Advantages :

There are numerous advantages in using Postman software. Some of the crucial points are stated below :

- a) Simplicity is the greatest advantage of this tool[17];
- b) It is one of the powerful tools with friendly interface[17];
- c) Illimitable compilations, atmospheres, tests and assets[17];
- d) It has the ability to save the data history of each and every API Request[17];
- e) It can test automatically with features of collection runner[17];
- f) It can generate and host browser-based API documentation simultaneously in real-time for users collections automatically[17];
- g) Pseudo servers can simulate every endpoint to review the mandatory response with no change in back-end[17].

4.4.3 Disadvantages :

There are few disadvantages of using this tool:

- A beginner can be overwhelmed from having to select from too many options[74];
- One cannot accurately say that an API developed in Postman will be a irrefutable shot work in browser[74];
- There are some limitations in the area of application such as API testing as well as some other techniques[74].

4.4.4 Features of Postman:

Postman provides a user-friendly interface which is simple in operation. If user wants to send a simple request, they only have to enter it, fill in the required headers, click the selected HTTP method, and then tick the ‘send’ button [75].

a) **One of the greatest features in Postman is the Postman Scripts:** To vindicate separate API responses, it can create specific JavaScript test scripts which is one of most renowned features of Postman. For beginners in writing test scripts, Postman offers code snippets provided examples of confirmations for response time and response code, etc. It also approves scripts that can run before an actual request has been sent. Those scripts are known as pre-request scripts [75].

b) **Collection features of Postman:** This is another remarkable features for this tool. It has a capacity for coordinating all requests into different folders. It is very important as more and more tests are being run. The developers can create their own test sets and then share them with other people. Postman can save data in the JSON format and can import them later. To create a collection, the simple and easy way is to click on the "Create a Collection Button" situated on the left panel and eventually fill in the blanks for collection name and detail[75].

c) **Postman Monitor can test Automation:** The third remarkable feature from numerous features of Postman is the Postman Monitor. It can keep running data collections automatically with defined intermissions from anywhere in the world. In this tool, Engineers can create test scripts, add them to collections, and therefore, create Postman monitors. This allows them to check if API endpoints operate properly or not and return appropriate data .Hence, it helps them to save time and energy[75].

APIs can be observed from the Postman website, after a monitor has been introduced.

4.4.5 The necessity of Postman in our project :

The reason behind enacting Postman for this thesis is mainly to verify the data for the user interface implementation.

Quality control in a development environment averts users from making and repeating mistakes in detecting faults. The optimal test organization maneuvers an aggrandized test suite, runs vast iterations of variables, roots out plenty of bugs, and stimulates developers to dwindle the time to upgrade [76].

With regulating through Postman, APIs has the potentiality to be reduced to

become the source of truth, experimenting and monitoring can be automated, and information and data are transitioned between users and developers in a similar work space around the API [76].

Comparison between Postman vs Other Tool

The biggest competitor for Postman in the API field is considered to be **The Insomnia**[1]. But Postman has numerous advantages which gives it ascendancy over other tools especially Insomnia for the same purpose . Postman is dubbed as “*the Only Complete API Development Environment*”[77] over others.

Postman appears to have a much divergent full-fledged set of products and features than expressly Insomnia ;when the users rush to truly swoop into its documentation.

4.5 Plotly :

4.5.1 Introduction to Plotly:

One of the popular platforms for visualizing data is known as Plotly. It can used with Julia, R, Python and many other languages. Plotly is prominent for incredible user-friendly orientation. It has a rich library with impressive documentation that enables user to visualize various graphs and charts with some simple lines of coding. The greatest advantage is by using Dash, it has a potential to utilize the graphs to the web as web apps. The object-oriented API of Plotly is called graphobjects. It has some similarity with object-oriented API of Matplotlib. It was established by Alex Johnson, Jack Parmer, Chris Parmer, and Matthew Sundquist [78].

4.5.2 Library of Plotly :

The library of Plotly, known as plotly.js is a browser-based charting library. It was created on the open source JavaScript graphing library. Plotly.js is known “a high-level, declarative charting library. Plotly.js ships with 20 chart types, including 3D charts, statistical graphs, and SVG maps.” The library is created with the help of

d3.js and stack.gl. The library operates through the HTML widgets configuration and also the framework is completely local [19].

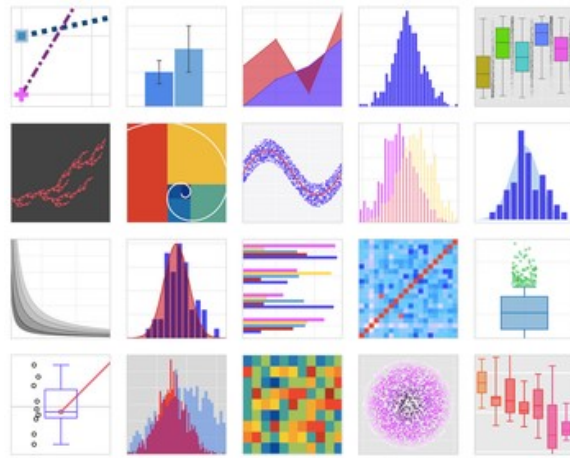


Figure 4-4: : Library for Plotly graphs [18] .

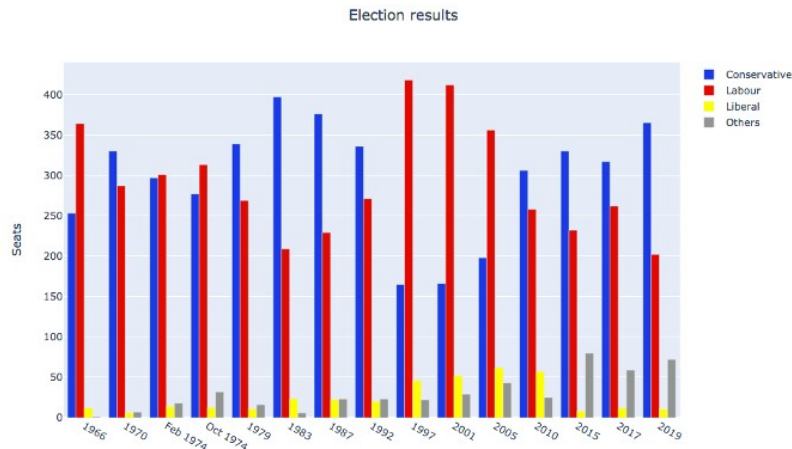


Figure 4-5: : Data of Election Results is plotted in bar using Plotly [19] .

4.5.3 The main products of Plotly:

There are numerous products that are included in Plotly. The major ones are stated below :

a) **Dash:** It is an open-source structure based on Python and R framework. It is used for building web-based analytic applications [78].

b) **Dash DAQ:** Dash is used to build this application. It is an open-source system which is created for the development of data acquisition GUIs. Dash DAQ is employed for the purpose of implementing with scientific instruments [78].

c) **Chart Studio:** It is used for importing and visualizing data into a grid. It has a graphical user interface for implementing stats tools. The graphs here are faster and more competent [78].

d) **Plotly Apps:** It is used for Google Chrome [78].

e) **Plotly Enterprise:** It is an on-premises installation package of Plotly[78].

f) **Plotly.js:** It is a JavaScript library, open source in structure. The library is made for creating graphs and dashboards[78].

g) **Figure Converters:** It has an ability to transform ggplot2, matplotlib, and IGOR Pro graphs into collaborative digital graphs[78].

h) **API libraries:** It can be applied for R, Python, MATLAB, Julia,Node.js, as well as Arduino and a REST API [78].

4.5.4 The reason behind selecting Plotly as Visualization Technique for our Project :

One of the fringe benefits for employing Plotly in any research is to acquire the user interactive visualizations ability [[79]].This reason in itself is enough for prizing Plotly superiority over other tools such as **Matplotlib** or **Seaborn** etc.

Having to implement user-interface online for visualization of data regarding energy consumption, we had no qualms but to select Plotly for the said purpose due to this huge benefit alone.

Comparison with other tools :

- As Seaborn and Matplotlib graphics are typically static, Plotly charts allow user to dwell over values and zoom in/out graphs, such as illuminating outliers from a large number of data points or ascertaining anomalies in time series plots[79]

- Frameworks like Tableau, Superset or Kibana, features such as dropdown that endorse only one data table as an input per graph. As a result, it transpires to be tiring to do a complex visualization of multiple sources. On the other hand, Plotly, permits users for developing charts that encompass manipulation and calculation of more than one table in database.

Chapter 5

Validation through Implementation And Results :

5.1 Hardware Implementation:

The smart meter documents production and/or consumption of electric energy and allows two-way communication between the meter and remote systems at gas, water and electric utilities.

Communications from the meter to the network can be done through 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, and Wi-SUN (Smart Utility Networks) etc[80].

For the execution of the experiment , first we have to set up the smart meter. A **CEM C20** meter was assembled in **Gijon Smart Cities Demo Lab** for this purpose. 'IP-SetUp' software [81] was used to configure the smart meter with the PC. The following procedures were as follows:

- a) First we have to select which smart meter we want to configure;
- b) Upon selection, the configuration box will appear ;
- c) Last but not least user has to fill up i.MAC id, ii.IP Address, iii.Netmask, iv. Gateway to fully equip .

The Server In Use :

We have connected the Smart Meter to the **server** of the **Gijon Demo Lab**.



Figure 5-1: : Server.

The readings from the meter :

For testing , one phase of the load was given as input . The output can be reckoned as followings :

Energy reading :

The formula that cohorts energy and power is: **Energy = Power x Time**. The unit of energy is known as joule, the unit of power is the watt, and the unit of time is the second.

Because the joule is very small to measure, electrical energy provided to consumers is bought by the UNIT or kilowatt hour (kWh).One kilowatt hour is the amount of energy that would be transferred by a one thousand watt appliance per hour.

Electrical supply authorities employ the **kWh** as the unit for measuring electrical energy to householders.

It can be perceived from the reading that meter was showing **0kWh** or no energy as it was not connected to any load or in our case **Server** .

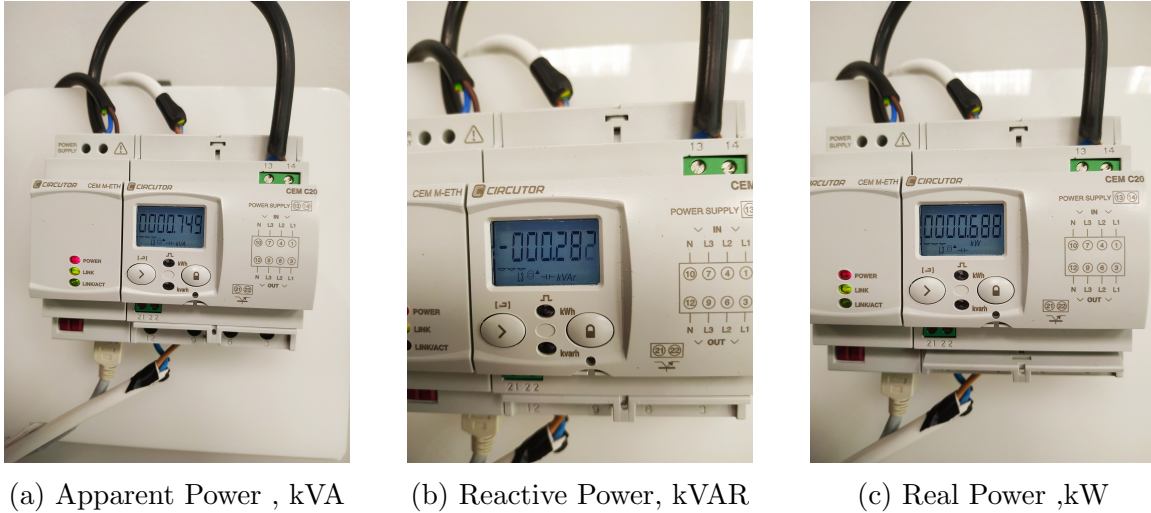


Figure 5-2: Smart meter Power reading of phase 3

After connecting it to the server, the reading from the meter can be seen as **0.2kWh**.

The Power Readings :

Power in an electric circuit is the rate of flow of energy for a definite period of the circuit.

The power reading from the Smart Meter comprises of :

- **Active Power :** The power which is typically absorbed or exploited in an AC Circuit is called True power or Active power or Real power. It is measured in kilowatt (kW) or MW. It is the actual output of the electrical system which runs the electric circuits or load.

The reading of active power on the smart meter in use is 0.686 kW oh L3.

- **Reactive Power:** The power which flows back and forth which implies that it moves in both the directions in the circuit or reacts upon itself, is called Reactive Power. The reactive power is measured in kilo volt-ampere reactive (kVAR) or MVAR. The reading can be both positive or negative.

The reactive power from the smart meter can be measured as -0.282 kVAR [shown in Figure 5-2b].

The point to be noted here is that the calculated reactive power is negative. The production of negative reactive power depicts that it is flowing from the utility grid (source) to the generator. This occurs whenever the generator field is under-excited or if an induction generator is being deployed as load [82].

It is also worth mentioning that some manufacturers practice the opposite sign convention and evaluate negative reactive power as inductive [82].

- **Apparent Power:** The coalescence of reactive power and true power is known as apparent power, and it is the product of a circuit's voltage and current, without reference to phase angle.

Apparent power is calculated in the unit of Volt-Amps (VA) and is symbolized by the capital letter S.

The measured apparent power in the system can be seen as 0.749 kVA [shown in Figure 5-2a].

Current

The current is typically the ratio of the quantity of charge and time.

The current calculated from the meter was 3.28A [shown in Figure 6-5]

The voltage

In short, voltage = pressure, and it is measured in volts (V). **The reading of the single phase voltage is 240.7 V**

The PF or Power factor

The power factor from the meter was calculated as 0.92 Referring to figure 5-3c.



(a) Current



(b) Voltage



(c) Power Factor

Figure 5-3: Smart meter Current, Voltage and PF reading of phase 3

5.2 Implementation Of The Project -Software Part And Result

5.2.1 User Interface

The user interface (UI) is the point at which human users interact with a computer, website or application. The goal of effective UI is to make the user's experience easy and intuitive, requiring minimum effort on the user's part to receive maximum desired outcome [2].

In this **thesis**, initially to test the project online, an online account has been set up for the user application and the the execution was perceived as successful. **The Main** page can be observed as in **Figure 5-4**.

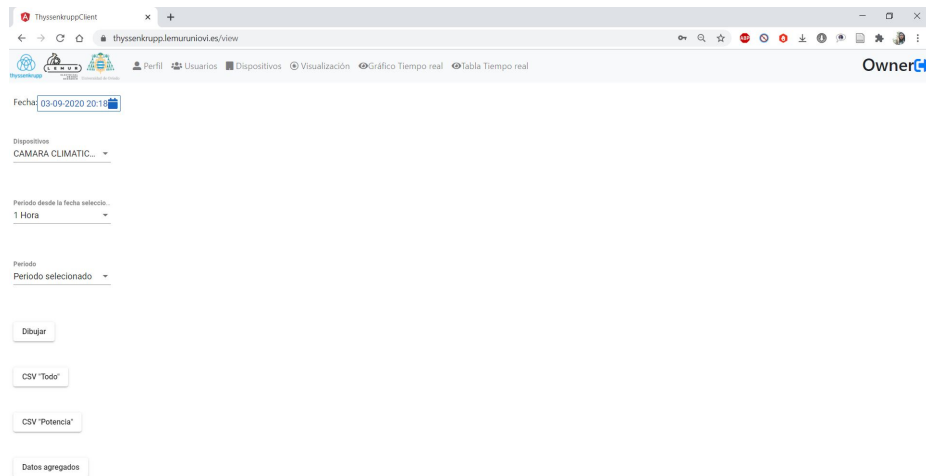


Figure 5-4: The User Interface

Log-In and Log-Out :

In computer security, Log-in is considered as the key to the system. It is simply the measures by which an individual acquires access to a computer system by identifying and authenticating themselves. The user credentials are typically some form of "user-name" and a matching "password", and these credentials themselves are sometimes referred to as a login .

However, before accessing the page, as we have mentioned in **chapter 4: Request Session**, it is pre-requisite to **log -in** first .

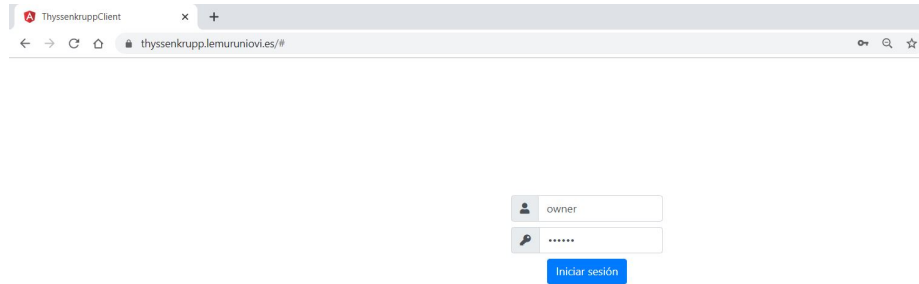


Figure 5-5: The Log-In Page

In the figure 5-5, the log -in has been made via owner user . Anyone can access the data if they have pre-determined user -id and password. Without the user credentials; i.e; id and password- entering the website is deemed impossible. Therefore, it validates the security and credibility of the website.

Moreover, **The Log-Out** determines the termination of a connection with a computer or system. Logging out is carried out to conclude access to a computer system or a website. It conveys the computer or website the information that the latest user wishes to terminate the ongoing login session.

After logging-out , a note at the bottom; was initiated confirming the departure from the page.

5.3 The Dashboard:

There are seven distinctive features in the dashboard. They are:

- Profiles

- Users
- Devices
- Visualization
- Real time graphs
- Real time table
- Comparison between device

The Profile:

If any user desires to change their user information or password , it can be accomplished by accessing the **Profile** section .

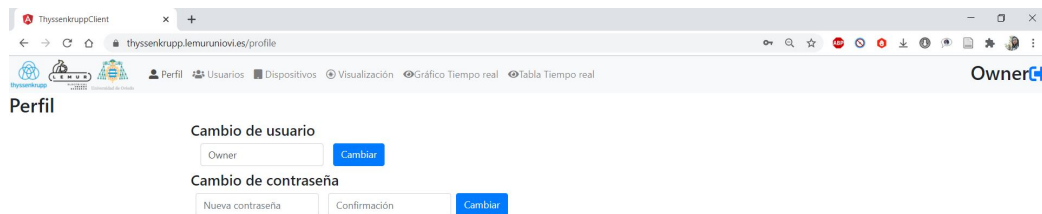


Figure 5-6: The Profile Page

As indicated in the figure 5-6, for changing the password, the operation can be completed by creating a new password and confirming that one.

The User:

The management level power of the four designated users are given bellow in the table 5.1 :

| Management Levels | Profiles | | | |
|---------------------------|----------|---------------|----------|---------|
| | Owner | Administrator | Engineer | Visitor |
| Administrators management | ✓ | × | × | × |
| Users management | ✓ | ✓ | × | × |
| Devices management | ✓ | ✓ | ✓ | × |
| Data Visualization | ✓ | ✓ | ✓ | ✓ |

Table 5.1: Profile of Visitor

From the above table, we can see that the owner has the all management level powers. The administrator can have power over user, devices or data visualization level but they have no right over other administrator. Hence administrator cannot manage other administrator. Meanwhile, the engineers cannot supervise the owner or the administrator but they can control the user or visualization level. They can see some data and also add/delete/edit any device in the system. On the other hand, the visitor has nothing but only the data visualization management power

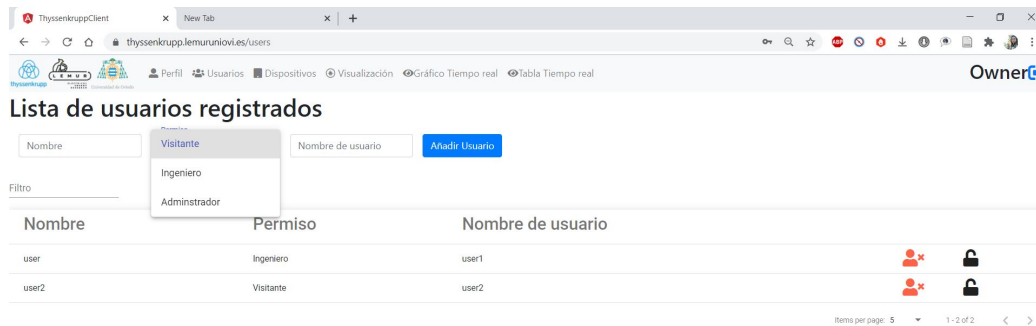


Figure 5-7: The User List

As the page was accessed by an owner user, the remaining three types of user are seen for registration in the following figure.

i) Owner;

The owner has universal control over the other administrator, engineers or visitors. They can add/ delete any administrator, engineer or user.

For adding any new user, three parameters are necessary- a) Name of user, b)

type of permission for the new user , c) user id .

On the other hand ,to delete any user from the web-page, the owner has to simply click on the **blue-circled user-icon**. Referring to figure 5-8 :



| Nombre | Permiso | Nombre de usuario |
|--------|-----------|-------------------|
| user | Ingeniero | user1 |
| user2 | Visitante | user2 |

Figure 5-8: Removing any user from the website

ii) Administrator;

An administrator can only deal with engineers or visitors. Nevertheless, they can not manipulate other administrators or owner. In a nutshell ; they have no authority to add/delete or modify another administrator.

iii) Engineer;

They have the ability to add/delete any devices and visualize the data . Moreover, they have no administrative or user management power.

iv) Visitor;

They can only visualize the data .

The List Of Devices

The potentiality of adding/removing any device from the system has been granted to three types of users except the visitors. To add any device, some parameters have to be recorded in the list . They are : a) name; b) label; c) IP address; d) type; and e) description.

Four types of smart meters have been employed in our project .

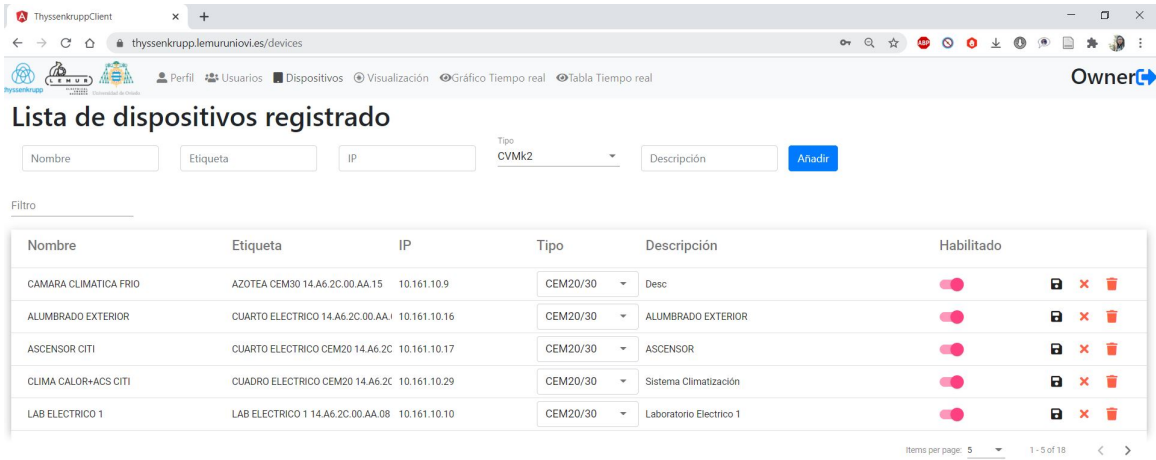


Figure 5-9: The Device List

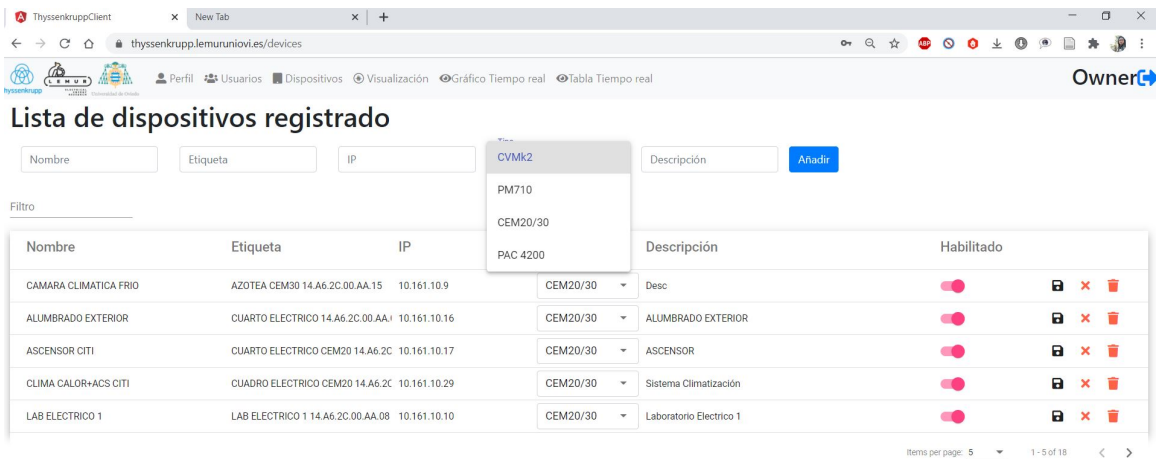





Figure 5-10: The 4 type of Smart Meter List

When a device is not connected to a smart meter, **an orange colored cross mark** appears beside the device (**shown in figure 5-11**).The mark turns into green tick mark after connecting with a smart meter . It affirms that now the device is coupled with a meter,

Filtro _____

| Nombre | Etiqueta | IP | Tipo | Descripción | Habilitado |
|-----------------------|-----------------------------------|--------------|----------|-------------------------|---|
| CAMARA CLIMATICA FRIO | AZOTEA CEM30 14.A6.2C.00.AA.15 | 10.161.10.9 | CEM20/30 | Desc | <input checked="" type="checkbox"/>    |
| ALUMBRADO EXTERIOR | CUARTO ELECTRICO 14.A6.2C.00.AA. | 10.161.10.16 | CEM20/30 | ALUMBRADO EXTERIOR | <input checked="" type="checkbox"/>    |
| ASCENSOR CITI | CUARTO ELECTRICO CEM20 14.A6.2C | 10.161.10.17 | CEM20/30 | ASCENSOR | <input checked="" type="checkbox"/>    |
| CLIMA CALOR+ACS CITI | CUADRO ELECTRICO CEM20 14.A6.2C | 10.161.10.29 | CEM20/30 | Sistema Climatización | <input checked="" type="checkbox"/>    |
| LAB ELECTRICO 1 | LAB ELECTRICO 1 14.A6.2C.00.AA.08 | 10.161.10.10 | CEM20/30 | Laboratorio Electrico 1 | <input checked="" type="checkbox"/>    |

Items per page: 5 1 - 5 of 18 < >

Figure 5-11: Confirmation for adding device to a smart meter

Visualisation :

Data visualization is the graphical demonstration of particulars and facts. It can be achieved through deploying visual features like graphs, charts, diagram and maps. There are plenty of tools for data visualization which provide a convenient way to view and apprehend patterns, outlines, and directions in data.

From the data visualization, we can check voltage, current and THD of any 3-phase energy system for the selected device .

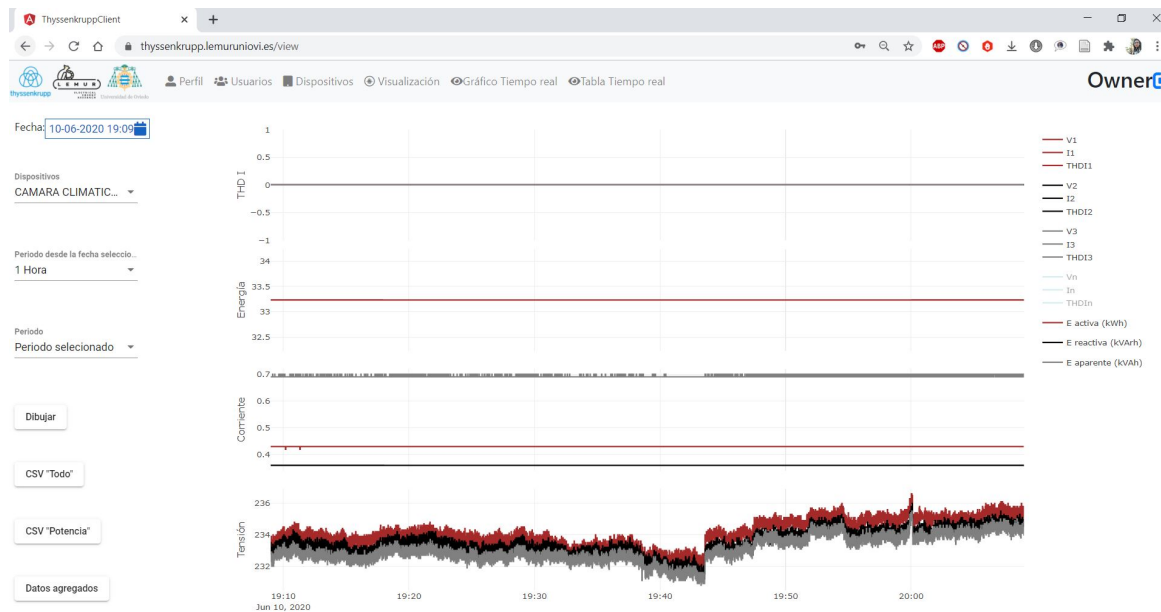


Figure 5-12: Process of Visualization [20]

In the present world, visualization equipment and software are crucial to examine vast amounts of information and construct data-driven decisions.

In the thesis; for the implementation of visualization of our data , **Plotly** is being employed to observe the data through **line charts**.

For the purpose of plotting the data in charts , we have processed **2 types of data** to visualise **-one for past data and the other is for real time data**.

The visualization page has the entry of past data .

We can choose any device from the list to apprehend the data .

User can choose to observe data over different period of time such as - for an hour, a day, a week, a month or a year.

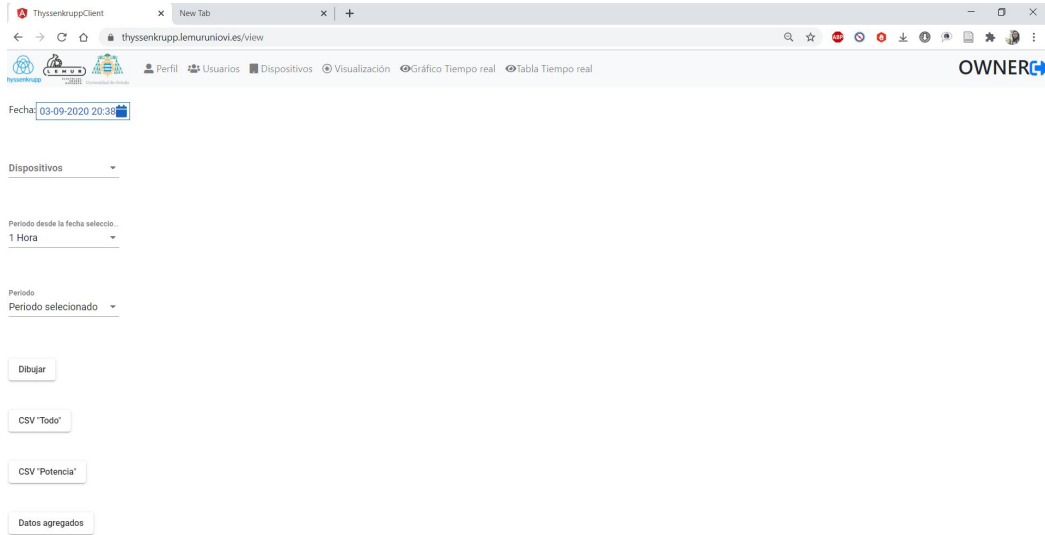


Figure 5-13: The Visualization Section

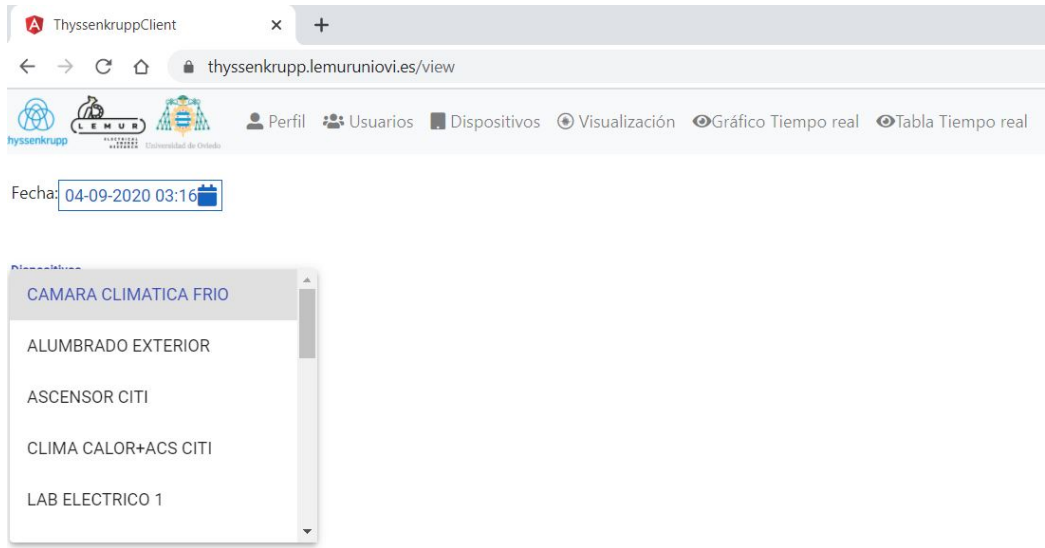


Figure 5-14: The data for a certain device

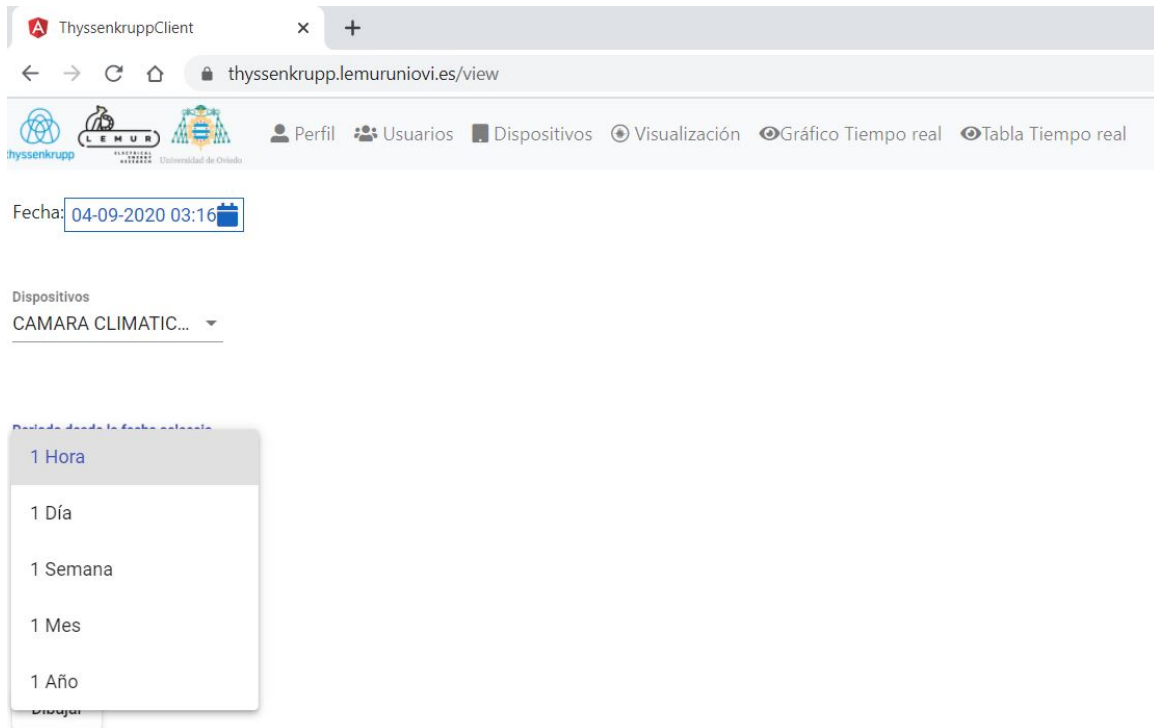


Figure 5-15: The data visualization for various time period

For the next step, we have selected various device for testing. The following information can be found from data - **3 phase voltage, THD and current value, neutral voltage , THD and current value and active, reactive and apparent power.**

The graph can be plotted for 1 hour, 1 day, 1 week , 1 month and 1 year

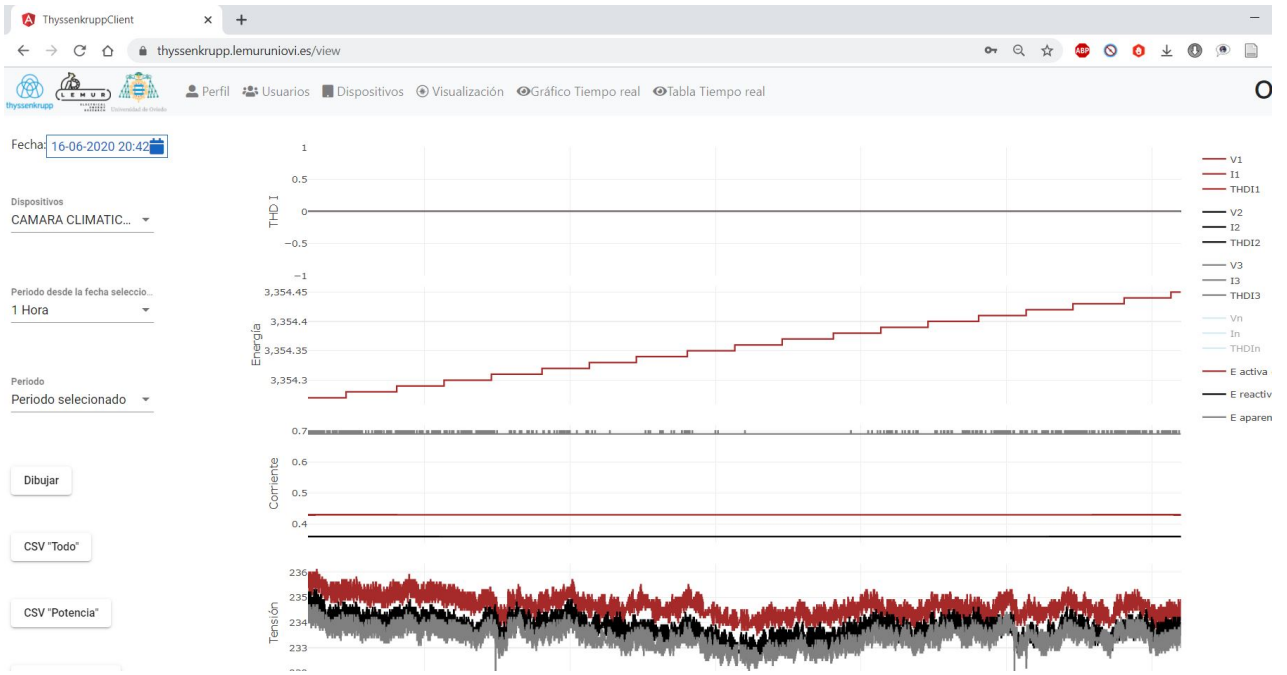


Figure 5-16: The data for 1 hour

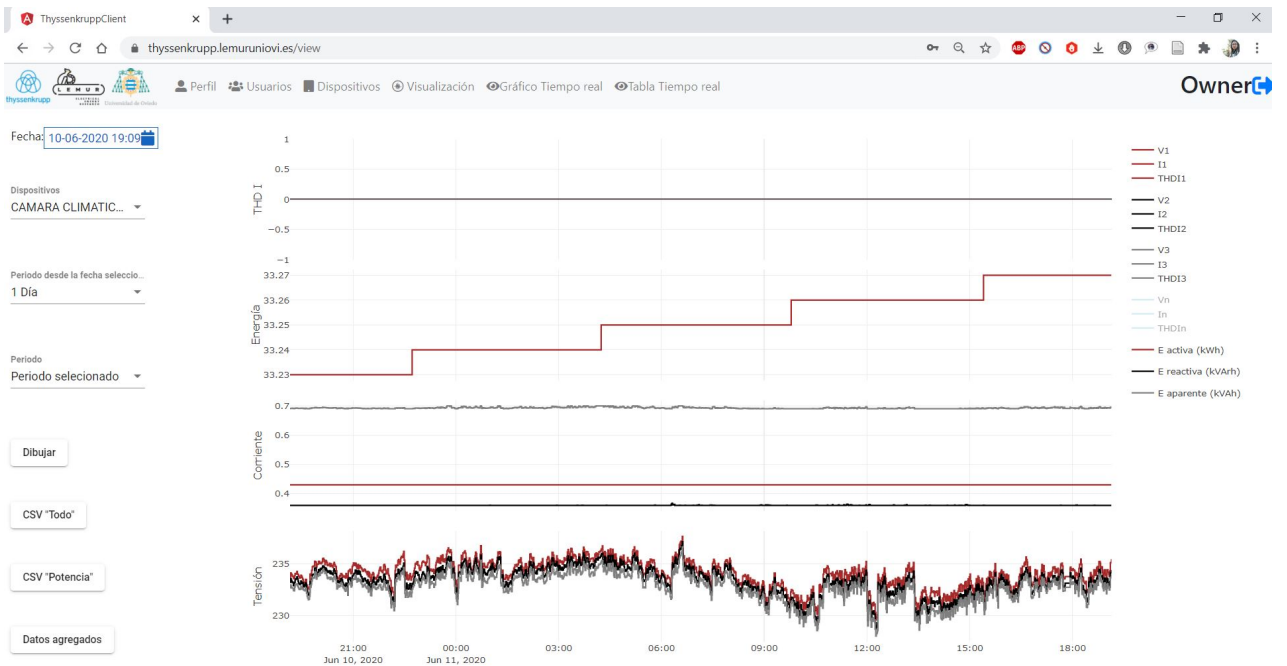


Figure 5-17: The data for 1 day

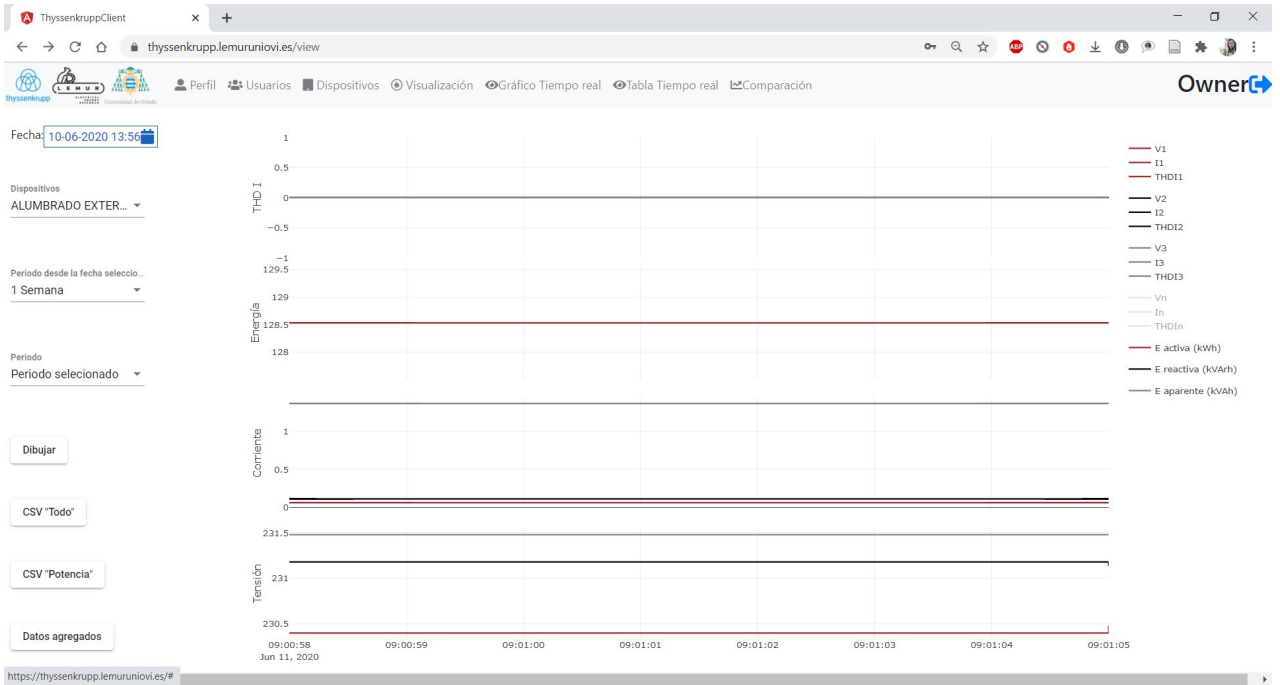


Figure 5-18: The data for 1 week

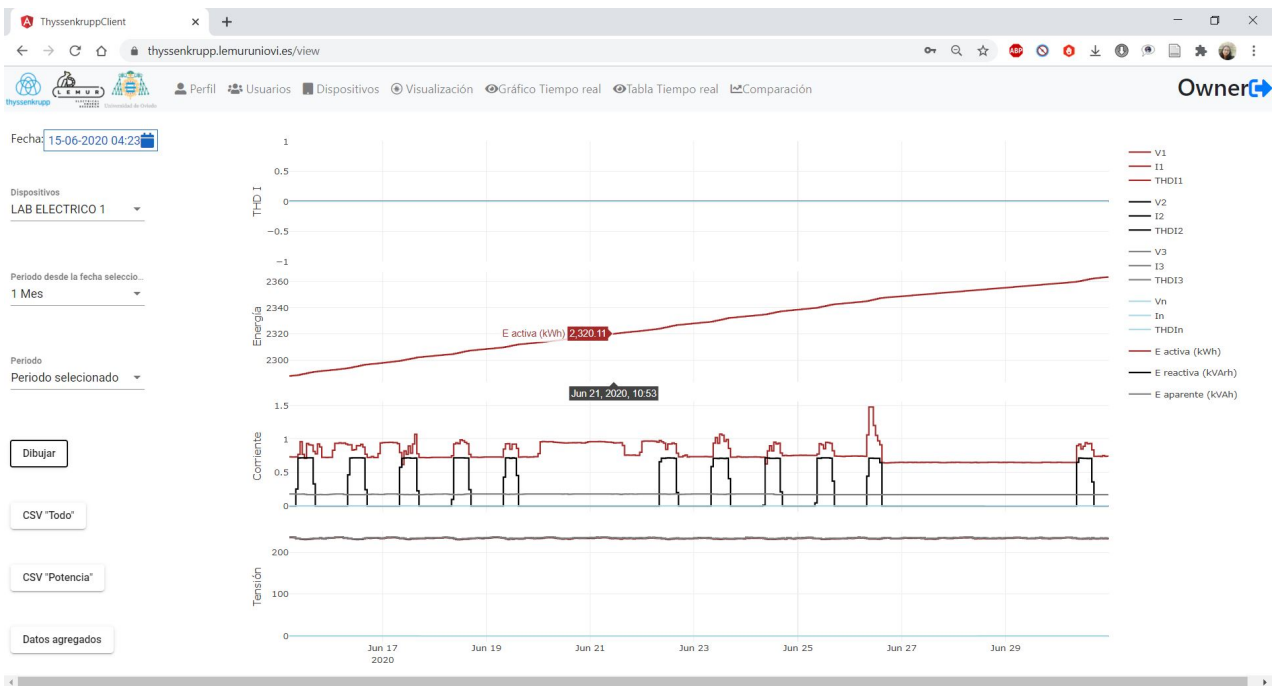


Figure 5-19: The data for 1 month



Figure 5-20: The data for 1 year

Real time Data :

Real-time data (RTD) is known as the set of data or information that can be provided immediately after collection.

There is no delay in the timeliness of the information provided to the user.

The real time visualizations of our application help the user to check for any sudden change in their usage . It helps the energy companies to prevent sudden anomalies or faults in the system.

Two types of real time data can be presented here.

- Real time chart[Figure5-21] ,
- Real time table [Figure5-22]

| Request Management | Function | Route | Method | Data Description |
|--------------------|----------|-----------|--------|---------------------------------|
| Data realtime | realtime | /realtime | GET | Parameters: -ID of the meter |

Table 5.2: Real Time Data Management

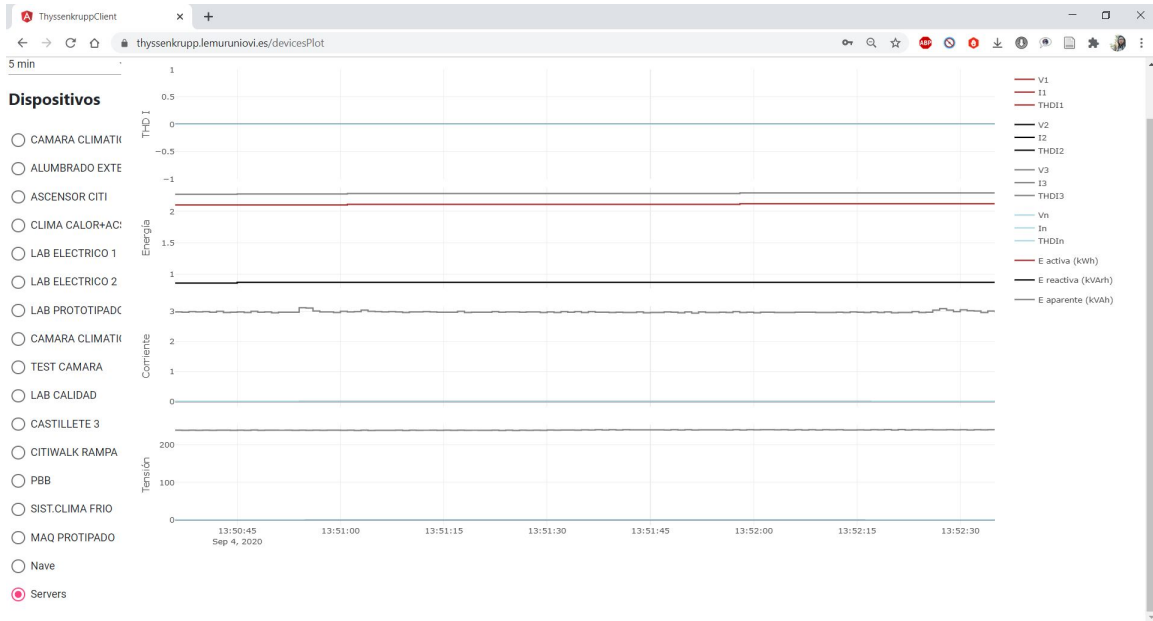


Figure 5-21: Real Time data Configuration

| Variable | Fase 1 | Fase 2 | Fase 3 | Fase n |
|----------------|------------|---------|-------------------------------|---------|
| Corriente | 000.00A | 000.00A | 002.95A | 000.00A |
| Tensión | 000.00V | 000.00V | 241.10V | 000.00V |
| THDI | 000.00% | 000.00% | 000.00% | 000.00% |
| CosPhi | 001.00 | 001.00 | 000.84 | |
| FP | 001.00 | 001.00 | 000.84 | |
| Energía activa | 016.550kWh | | Energía aparente 019.128kVAh | |
| | | | Energía reactiva 009.590kvarh | |

Figure 5-22: Table for Real Time data Configuration

5.3.1 Comparison Between Device

The following data is required before comparing between 2 devices

- The date to compare;
- The device to compare and their name ;
- The selection of the second device to compare with the first one;
- Select one from -current, voltage or THD to show ;
- Accept the changes to initiate the operation. **The necessity for comparing**

two devices :

-It helps us to determine possible abnormality of one device by comparing with the other one;

-If there is any sudden increase in consumption of energy for one user; energy utilities can easily verify them by comparing with another user device .

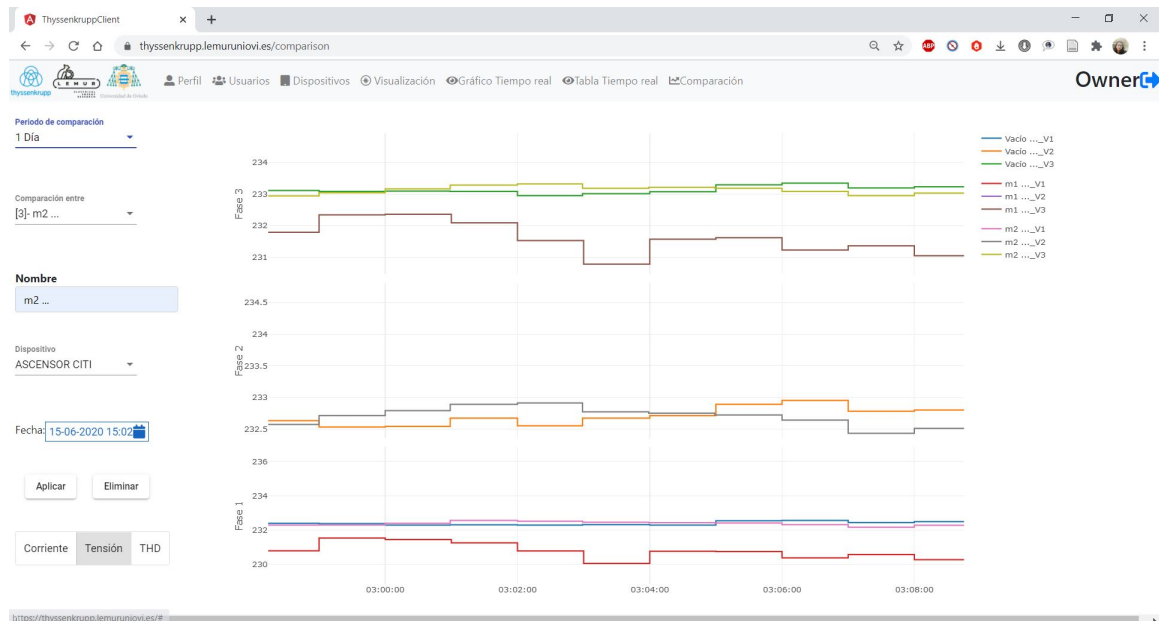


Figure 5-23: The data for voltage comparison between 2 devices

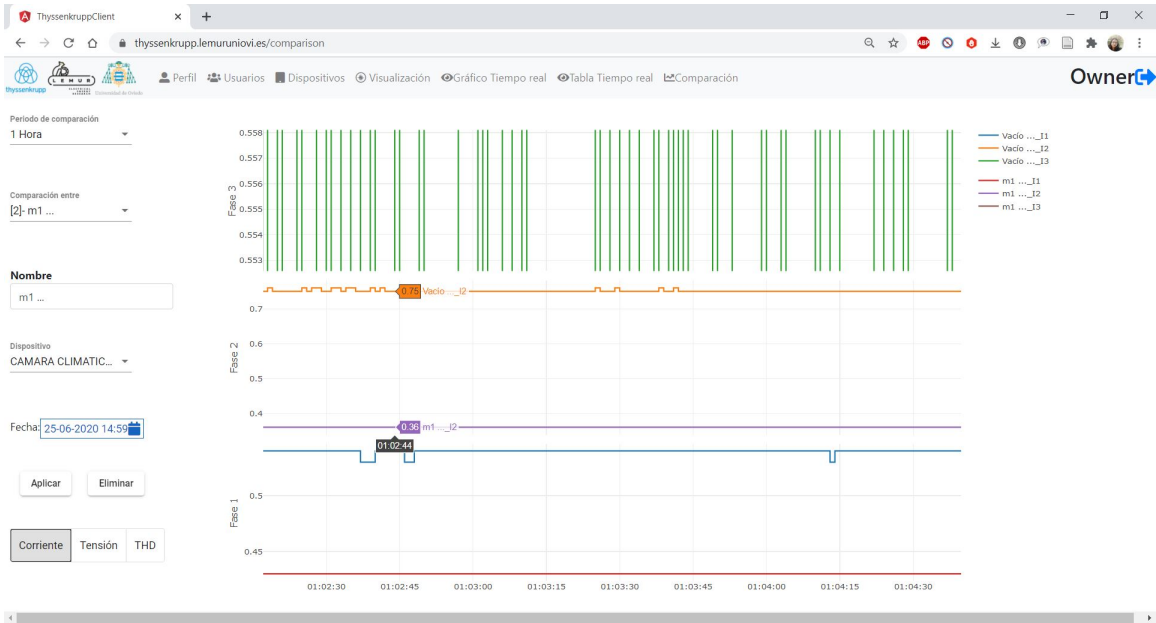


Figure 5-24: The data for current comparison between 2 devices

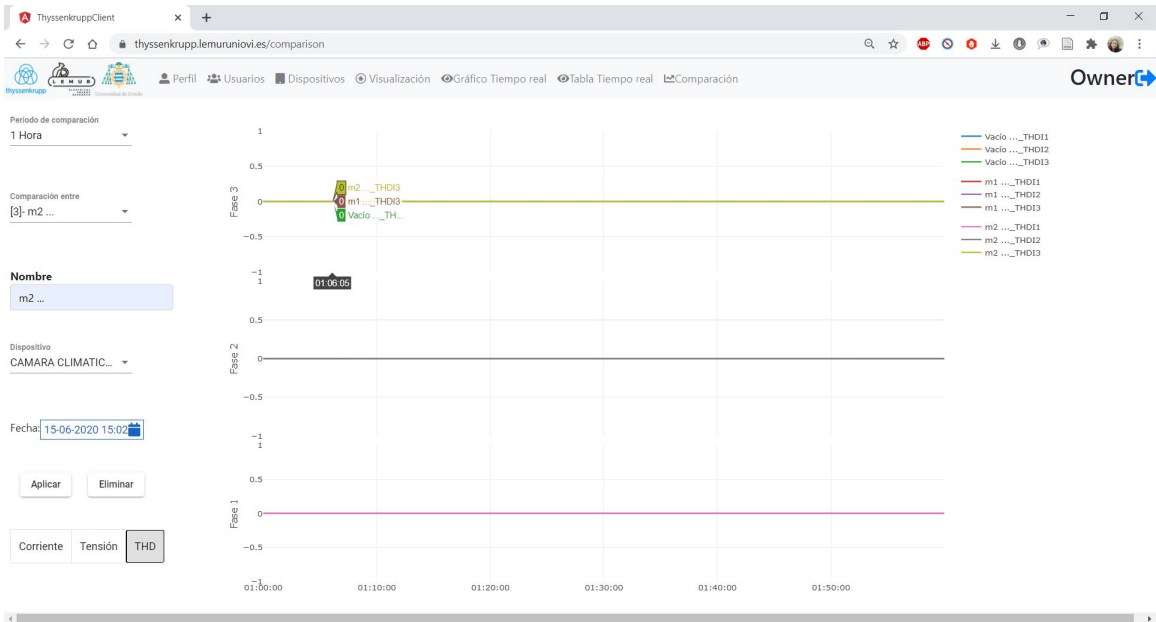


Figure 5-25: The data for THD comparison between 2 devices

Chapter 6

Conclusion and Future Work

6.1 Conclusion:

This thesis explores the visualization of one of the main issues associated with the development of efficient Building Energy Management Systems or BEMS which is **energy consumption** of any particular building .The ability to visualize data of consumption; dispense users with concerted proficiency for sorting, filtering,and analysing information, and take benefits of what **Ben Shneiderman** merits as the strong “**bandwidth of human vision**” [83].

The software implementation of different software such as **Node.js**, **Angular.Js** and **Plotly** etc was triumphant to address the challenges of managing huge amounts of dynamically changing data,BEMS being subject to varying provisions, and acquiring exorbitant information that can be wielded for amplified energy saving as well as optimal control over the total consumption.

The hardware implementation of setting up smart meter with the user-interface was concluded adequately.We have successfully attained set of data for UI application and validated them through the plotting .

In summary, the affirmation of successful completion of the project can be declared through the validation of achieving goals previously addressed in section 1.3.

BEMS or Building Energy Management System provides comfort to the owners as well as to the managers of the building , as it is their job to superintending various departments, their employees, need of users and environments so that both the building and its tenants are enjoying energy at maximum efficiency and pleasure.

Latest information regarding methodology and tools for visualization have been updated. They are being adopted in business, science and educational institutions for better understanding of trends and affiliations in colossal, complex data sets.

The Edge in Amsterdam and the Jeddah Tower are two of the glaring example of most up-to date building automation technologies so far [84], affirming that future is now on our doorstep, it is no longer confined in our dreams or any scientific labs. Automating buildings energy systems are now trying to pioneering real spaces to unravel persistent tasks of growing energy consumption, sudden faults or breakdown, and maintenance cost. This has resulted in some of the great alliances between governments and big farms to elevate the existing number of smart automated campuses, offices as well as facilities.

6.2 Future Work :

Future work generally embodies augmented inspection of specific infrastructure,new-found propositions to seek contrasting approaches, or simply curiosity.

Heaps of divergent modifications , tests, and inquisitions have been shunned for the future due to lack of time as collecting ample set of values for database management, conducting the experiments with different software, and then being programmed for visualisation are typically arduous, necessitating even days to finalize a single run.Moreover,due to the current situation with **COVID-19**, there were challenges for carrying out further practical test which have been left for subsequent time.

This thesis has been primarily focused on the functionality of two types of database management system for storing data;Angular and Plotly for plotting, comparing between different devices from distinct times and most of the functions used to find the

best result where obtained from data obtained from the previous projects leaving the detailed study of various other software or DBMS outside the scope of the thesis. In a nut shell, there are also many tools that could be deployed to attempt to solicit most pertinent conjunction towards the preeminent solution.

There are some propositions that I would have liked to investigate in the midst of the description and the progress of structure for the thesis in Chapter 4 and 5.

a) In this present era, everything that could be made as a component in the past, has transitioned into a miniature version of itself. As a result, almost every bit of the houses, the company or facilities are emitting a unending stream of metrics and events or **time series** data through the use of smart phone or smart devices.

It implies that the rudimentary platforms need to emerge to back these new emerging workloads which demand for a paradigmatic shift in how we approach our data infrastructure. Therefore, time series database is in crying need now.

Time series databases have fundamental architectural design configuration that enable them very incompatible from other databases. These include data life cycle management, time-stamp data storage, compression and summarizing of data, capacity to withstand large time series dependent scans of ample records, etc [85].

Scalibility is one of the **major issues for SQL databases**, therefore, they are often tagged as that they don't scale well. However, Time-series database works like a magic for scaling the data.

As though we didn't employ any time series database in our project for storing data, it can be a notable future work if different time-series database can be used here. As we have to store a quite a lot of data, several time-series database such as **GriddB** or **influx-dB** can play a vital role here. This can pave for a great future work. Therefore, I would like to venture in this area of research during the time for my PhD.

b) **Plotley** was instrumental in this thesis to visualize the data from Smart Meter. However, **OmniSci** can also be used here for the same purpose. It can provide utility companies the opportunities to visualize and interact with customer in real time at **high speed**.

c) To externalize visualization, the values were plotted in line charts in the project. Multifarious groups of charts such as **Bar charts, Pie Charts, Scatter Plots** can be implemented for this purpose.

d) **ThingsBoard** can be implemented here as a means of IoT smart metering solutions and data visualization .

e) Due to the **COVID-19** situation in the year of 2020, physical distancing has become new norm. As a result, most of the working facilities have ensured their worker to be able to work from home. Therefore, people remain at home most of the time which may lead to sudden increase in energy consumption and cost management of user. The Building Energy Management Companies are pondering for possible solutions on how to utilize this current situation [86].

f) For health and safety reasons, it is discerning to transit into touch less services everywhere in future. As a result, some common facilities such as transactions of vending machine or usage of elevator in building will have to work via user smart phone without requiring touching the surface. Transactions should not require touching physical assets, instead, smart devices such as phones and vending machines should be able to communicate with each other to complete transactions. BEMS companies can work in this area in future by creating a smart paragon with automation and IoT based structure so that the amenities in the building that is used by everyone can be made contact less.

g) Building Management Energy Saving or BEMS technology can be used in big Airports also for sustainable development and energy savings [87].

Appendix A

Tables

| | | |
|------------|-----------|------------------|
| Parameters | Binary | SQLite (integer) |
| 1 day | 108 ms | 1500 ms |
| 30 Day | almost 3s | more than 300 s |

Table A.1: Data Reading Speed

| Request | Function | Route | Method | Description |
|----------------|-----------------|--------------|---------------|---|
| Session | Login | /session | POST | i)Send user data for login. ii) Necessary parameters : -Username -Password |
| Session | Logout | /session | DELETE | i)Log out the logged in user. ii) No parameters needed. |

Table A.2: Session.

| Request | Function | Route | Method | Description |
|---------|-----------|-------|--------|--|
| User | addUser | /user | POST | i)Add a new row to the user database. ii)Parameters: -name -username -password |
| User | delUser | /user | DELETE | i)Delete rows from the user database. ii)Parameters: -id |
| User | editUser | /user | PUT | i) Edit parameters of any rows . -Updates the values for full row. ii)Parameters: -id -name -username -password -permission |
| User | listUsers | /user | GET | i) Returns the list of users in the database. ii) No parameters. |

Table A.3: User Management.

| Serial | Parameters | Resolution | N° of Samples | Chart Type |
|--------|------------|------------|---------------|------------|
| 1 | 1 hour | seconds | 3600 | Line chart |
| 2 | 1 day | minutes | 4320 | Line chart |
| 3 | 1 Month | Hours | 2620 | Line Chart |
| 4 | 1 year | days | 365 | Line chart |

Table A.4: Presentation of Data History.

| Request | Function | Route | Method | Description |
|---------|------------|---------|--------|--|
| Device | addDevice | /device | POST | i) Add a new row -name -I.P Address -type -disabled |
| Device | delDevice | /device | DELETE | i)Delete rows from the user database. ii)Parameters: id |
| Device | editDevice | /device | PUT | i) Updates a row in the user database. ii) Parameters: -id -name - I.P Address -type -disabled |
| Device | listDevice | /device | GET | i)Returns the list of meters in the database. ii) No parameters. |

Table A.5: Device Management.

| Request Management | Function | Route | Method | Description of the data history |
|--------------------|----------|----------|--------|---|
| Data history | history | /history | GET | Parameters: -ID of the meter ; -Period (From to To) |

Table A.6: data history Management.

Bibliography

- [1] M.P. Papazoglou. Distributed database architectures. In *Proceedings. PARBASE-90: International Conference on Databases, Parallel Architectures, and Their Applications*, pages 549–, March 1990.
- [2] What is SQLite? Top SQLite Features You Should Know.
- [3] Energy Management | AYGAZ.
- [4] Frost & Sullivan. Strong Opportunities for the European Energy Management Market Set to Double by 2018, finds Frost & Sullivan.
- [5] BSRIA. BSRIA World Market Intelligence Industry Briefing - AHR Expo 2016.
- [6] Designing Smart Meters with Circuit Protection, Sensing, and Power Control Capabilities - Industry Articles.
- [7] All You Need to Know About Fronius Smart Meter, May 2020. Section: Solar Meters.
- [8] Power and power quality analyzers : CVMk2 Series.
- [9] PM710MG - power meter PM710 - basic readings, THD + min/max + RS485 | Schneider Electric Singapore.
- [10] AC measurement : CEM-C20 series (consult availability).
- [11] PAC 4200 Class 0.2s Modbus TCP | Fluitronic.
- [12] Server, June 2020. Page Version ID: 962770785.
- [13] How Does Modbus Communication Protocol Work? | RealPars.
- [14] OZEKI - Frame format Modbus TCP.
- [15] Node.js - Introduction - Tutorialspoint.
- [16] Why Node.js is the Best Option to Develop a Chat-based Mobile Application?, May 2016. Section: Mobile Apps.
- [17] Chanchal Chauhan. Postman – Proxy and Mock Server, November 2017. Section: HTML5 / CSS / JS.

- [18] Simplify data visualization in Python with Plotly | Opensource.com.
- [19] Paul C. Bauer & Richard Traunmüller. *Interactive Data Visualization (2nd Day)*.
- [20] Maria Stefan, Jose G. Lopez, Morten H. Andreassen, and Rasmus L. Olsen. Visualization Techniques for Electrical Grid Smart Metering Data: A Survey. In *2017 IEEE Third International Conference on Big Data Computing Service and Applications (BigDataService)*, pages 165–171, Redwood City, CA, USA, April 2017. IEEE.
- [21] MODBUS, March 2019.
- [22] Rajesh Kumar, Kuldeep Khatri, Muhammad Imran, and Hasan Ali Khattak. Towards Smart Utility Monitoring and Management. In *2019 2nd International Conference on Communication, Computing and Digital systems (C-CODE)*, pages 77–80, March 2019.
- [23] Building Energy Management Systems (BEMS) | Climate Technology Centre & Network.
- [24] Introduction To Energy Management - PowerPoint Slides.
- [25] Building Energy Management Systems (BEMS) | Climate Technology Centre & Network.
- [26] Khairy Sayed and Hossam A.Gabbar. *Building Energy Management Systems (BEMS)*, pages 15–81. 06 2018.
- [27] Energy Management Software Frequently Asked Questions [FAQ], September 2019. Section: Blog.
- [28] Europe Building Energy Management Systems (BEMS) Market (2017-2022).
- [29] Building Energy Management System (BEMS) Market 2020: Global Industry Size, Share, Future Challenges, Revenue, Demand, Industry Growth and Top Players, Schneider Electric, Siemens, Honeywell Analysis to 2026.
- [30] Sergey Guzhov and Alexander Krolin. Use of big data technologies for the implementation of energy-saving measures and renewable energy sources in buildings. In *2018 Renewable Energies, Power Systems Green Inclusive Economy (REPS-GIE)*, pages 1–5, April 2018.
- [31] Takayuki Itoh, Masato Kawano, Shuji Kutsuna, and Takeshi Watanabe. A Visualization Tool for Building Energy Management System. In *2015 19th International Conference on Information Visualisation*, pages 15–20, July 2015. ISSN: 2375-0138.

- [32] Yasutomo Matsuoka. Building communications system: Takenaka’s M2M platform for building management application interface. In *Proceedings of PICMET ’14 Conference: Portland International Center for Management of Engineering and Technology; Infrastructure and Service Integration*, pages 1746–1758, July 2014. ISSN: 2159-5100.
- [33] Muhammad Fahim and Alberto Sillitti. An Anomaly Detection Model for Enhancing Energy Management in Smart Buildings. In *2018 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm)*, pages 1–6, October 2018.
- [34] Rick Diamond, Mike Opitz, Tom Hicks, Bill Von Neida, and Shawn Herrera. Evaluating the Energy Performance of the First Generation of LEED-Certified Commercial Buildings. page 12, 2006.
- [35] Savanna New, Hannah Nano, Jerrad Havemann, Zian Wang, Mitchell Posey, Ernie Hogan, Khoi Chu, Devin McCormick, Tarrek Youssef, and Bhuvaneshwari Ramachandran. Design and Implementation of a Real-Time Energy Monitoring and Reporting System. In *2019 North American Power Symposium (NAPS)*, pages 1–6, October 2019.
- [36] Zhishu Shen, Tiehua Zhang, Jiong Jin, Kenji Yokota, Atsushi Tagami, and Teruo Higashino. ICCF: An Information-Centric Collaborative Fog Platform for Building Energy Management Systems. *IEEE Access*, 7:40402–40415, 2019. Conference Name: IEEE Access.
- [37] Z. H. Bohari, R. Ghazali, N. N. Atira, M F Sulaima, A A Rahman, and M K Nor. Building energy management saving by considering lighting system optimization via ANOVA method. In *2018 4th International Conference on Computer and Technology Applications (ICCTA)*, pages 216–220, May 2018.
- [38] The Modbus Organization.
- [39] An overview of HTTP.
- [40] Smart meters vs normal meters - Zoopla MovePlanner.
- [41] Smart meters: the advantages and disadvantages, May 2019. Section: Meters.
- [42] Smart Meters | Disadvantages and Advantages - Flipper.
- [43] Ross Anderson and Shailendra Fuloria. Who Controls the off Switch? In *2010 First IEEE International Conference on Smart Grid Communications*, pages 96–101, Gaithersburg, MD, USA, October 2010. IEEE.
- [44] Baudouin. FBI: Smart Meter Hacks Likely to Spread — Krebs on Security.
- [45] Center for Electromog Prevention.

- [46] Stuifmeel Bv. Multi-function electrical energy meters. page 2.
- [47] 7KM4211-1BA00-3AA0 | Siemens SENTRON PAC4200 Graphical, LCD, Monochrome Digital Power Meter, 92mm x 92mm, | RS Components.
- [48] (PDF) Smart Meter Data Analytics: Systems, Algorithms, and Benchmarking.
- [49] Modbus FAQ.
- [50] Modbus Technical Resources.
- [51] Database, July 2020. Page Version ID: 970368775.
- [52] Nikola Obradovic, Aleksandar Kelec, and Igor Dujlovic. Performance analysis on Android SQLite database. In *2019 18th International Symposium INFOTEH-JAHORINA (INFOTEH)*, pages 1–4, East Sarajevo, Bosnia and Herzegovina, March 2019. IEEE.
- [53] Ding Li, Yingjun Lyu, Jiaping Gui, and William G. J. Halfond. Automated Energy Optimization of HTTP Requests for Mobile Applications. In *2016 IEEE/ACM 38th International Conference on Software Engineering (ICSE)*, pages 249–260, May 2016. ISSN: 1558-1225.
- [54] Features Of SQLite.
- [55] Ching-Han Chen, Ching-Yi Chen, Chih-Hsien Hsia, and Guan-Xin Wu. Big Data Collection Gateway for Vision-Based Smart Meter Reading Network. In *2014 IEEE International Congress on Big Data*, pages 266–269, June 2014. ISSN: 2379-7703.
- [56] Xiufeng Liu, Lukasz Golab, Wojciech Golab, Ihab Ilyas, and Shichao Jin. Smart Meter Data Analytics: Systems, Algorithms, and Benchmarking. *ACM Transactions on Database Systems*, 42:1–39, 2016.
- [57] Aswin Raj C., Aravind E., Ramya Sundaram B., and Shriram K. Vasudevan. Smart Meter Based on Real Time Pricing. *Procedia Technology*, 21:120–124, 2015.
- [58] Node.js. About.
- [59] Django vs NodeJS: Difference Between Django and NodeJS, May 2020. Section: Full Stack Development.
- [60] Peter Wayner. Node.js vs. PHP: An epic battle for developer mindshare, April 2019.
- [61] Express.js, May 2020. Page Version ID: 958288615.
- [62] Express.js Mobile App Development: pros and cons of Node.js framework, June 2017.

- [63] Binariks: Outsourcing Custom Software Development company in Ukraine, November 2017. Section: Tools.
- [64] Node.js Express FrameWork Tutorial - Learn in 10 Minutes.
- [65] Express 3.x - API Reference.
- [66] Angular (web framework), August 2020. Page Version ID: 975226368.
- [67] AngularJS - Overview - Tutorialspoint.
- [68] Sumit Jaiswal says. What is angularJs, January 2017.
- [69] Wan-Noorshahida Mohd-Isa, Rubita Sudirman, and Sheikh Sh-Salleh. Angular features analysis for gait recognition. pages 236 – 238, 2005.
- [70] Angular - Introduction to Angular concepts. <https://angular.io/guide/architecture>.
- [71] The Good and the Bad of Angular Development.
- [72] Mindmajix Technologies. Top Reasons Why You Should Use Angular JS, April 2018. Section: AngularJS.
- [73] Postman | The Collaboration Platform for API Development.
- [74] Introduction to Postman for API Development, May 2018. Section: GBlog.
- [75] API testing: useful tools, Postman tutorial and hints.
- [76] Aviv Kaufmann. The Economic Benefits of the Postman API Platform. page 12, 2020.
- [77] Paige Niedringhaus. Postman vs. Insomnia: Comparing the API Testing Tools, May 2019.
- [78] Plotly, July 2020. Page Version ID: 967793582.
- [79] Moorissa Tjokro. The Sweet Spot of Plotly, January 2020.
- [80] Smart meter, August 2020. Page Version ID: 975943203.
- [81] Circutor - Distribuidor de Equipos Mejorar Eficiencia Energética.
- [82] Reactive Power | Continental Control Systems.
- [83] D Lehrer and J Vasudev. Visualizing Information to Improve Building Performance: A Study of Expert Users. page 12.
- [84] The Past, Present, and Future of Building Automation Systems.
- [85] Time Series Database (TSDB) Explained | InfluxDB.

[86] Building and testing APIs with LoopBack and Postman - Postman Blog | Postman Blog.

[87] AI.