UNIVERSITY of RWANDA

Research and Postgraduate Studies (RPGS) Unit

ACEIoT

POWER OPTIMIZATION BASED ON FUZZY INFERENCE SYSTEM AND IoT

Case Study: University of Rwanda, College of Science and Technology, AGACIRO Block Building

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A dissertation submitted in partial fulfilment of the requirements for the degree of Masters of Science in Internet of Things- Embedded Computing Systems at the African Center of Excellence in IoT (ACEIoT)

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DECEMBER 2020

DECLARATION

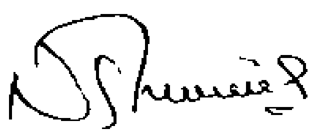
I declare that this research project report entitled “POWER OPTIMIZATION BASED ON FUZZY INFERENCE SYSTEM AND IoT-” is presented for the award of Master’s Degree in Internet of Things at African Centre of Excellence in Internet of Things, University of Rwanda is my own work. It has never been presented or submitted in any University or Institution of higher learning for the similar award.

Declared by:

JEAN LOUIS NIRAGIRE

African Center of Excellence in Internet of Things – University of Rwanda

November 30th, 2020



CERTIFICATE

This is to certify that the project work entitled "Power optimization based on fuzzy inference system and IoT" is the record of the original work done by Jean Louis NIRAGIRE with Reference number 215030228 in partial fulfilment of the requirements for the award of Masters of Science in Internet of Things, African Centre of Excellence in Internet of Things, University of Rwanda during the academic year 2020.

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ACKNOWLEDGEMENTS

I heartedly thank the World Bank which accorded me the financial support to be able to pursue Research under African Center of Excellence in Internet of Things. I would like to express my gratitude to all those which gave me the possibilities to complete this project. I want to thank the African Center of Excellence in Internet of Things for assisting me in my research and thank again the supervisors for giving me the permission to move on with this project.

I am deeply thankful to my supervisors Dr Damien HANYURWIMFURA and Dr Said NGOGA RUTABAYIRO whose help, stimulating suggestions; encouragement which helped me in all the time of research for and writing of this project. I also want to thank all my colleagues to all their assistances; to their encouragement they gave me as well as my neighbours and relatives part.

ABSTRACT

Electricity plays an outstanding role in daily life of a human being, from lightened homes, lightened roads, offices, schools, working and recreational areas. For electricity efficiency, measures and techniques are deployed to manage its usage. With the rise of new technologies and concepts, IoT and Machine learning concepts contributed a lot in optimizing many functions and systems and same techniques are hereby deployed to optimize power consumption. This research was conducted in University of Rwanda, College of Science and Technology, Agaciro Block building and it deploys an IoT system which yields the data of total room occupancy, the presence of electric current and voltage, the ambient room temperature and humidity, the presence and quantity of light and the presence of vibrations. The system has another part of Machine Leaning based Fuzzy Logic controller which is trained by using the fetched sensory data, hence a Fuzzy Inference System having Sets and Rules. The Agaciro block building has offices, conference rooms, computer labs, Server room, mechanical & chemical and soil testing laboratories, but this research only considers a single room as its scope. With the help of sensory prototype results, Matlab fuzzy logics based simulations, and the Matlab Simulink experimental results, this research proves its ability of optimizing the overall power consumption, as there is an an automation of existing campus power system to work under both supervised and unsupervised learning as the sensory data are used to train the machine learning based Fuzzy Logic Controller. The evaluation results show that the proposed optimization system save energy compared to the existing current power systems.

Keywords: Electricity optimization, IoT, Fuzzy Logics, Fuzzy Inference System, Supervised learning, Unsupervised Learning

LIST OF ACRONYMS

ACEIoT: African Center of Excellence in Internet of Things

AI: Artificial Intelligence

CT: Current transformers sensor

DC: Direct Current

DR: Demand Response

DVD: Digital Versatile Disc

DVR: Digital Video Recorder

FIS: Fuzzy Inference System

GA: Generic Algorithms

HEMS: Home Energy Management Systems

HVAC: Heating, Ventilation and Air Conditioning

IoT: Internet of Things

LAN IPv6: Local Area Network Internet Protocol version 6

LED: Light Emitting Diode

PDA: Personal Digital Assistant

PV: Photo Voltaic

RISC: Reduced Instruction Set Computer

Rwf: Rwandan Francs

TCA : Thermostatic controlling system

ToU: Time of Use

UAC-NFC: Unsupervised Automatic Clustering Integrated with Neural-Fuzzy Classification

UR-CST: University of Rwanda, College of Science and Technology

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1.1 Overview and Background

Electricity optimization has been the essential point in Electrification and Power Management Sector. The increase in need of access to electricity and electricity cost are the main causes for the need of optimizing electricity usage. To optimize Electricity, different techniques are modelled and deployed from production, grids and at the consumer sides. Some of the key researches include the introduction of Home Energy Management Systems HEMS [2], introduction of Internet of Energy [3], design of Heuristic-based shiftable loads [4], the use of Genetic Algorithms in the design of demand response optimization systems [5], deployment of short term energy storage using PV desalination Technology [6], the use Game Theory approach in decentralizing energy in micro-grids [7].

Internet of Things (IoT), as a state-of-the-art concept, when enhanced with Artificial Intelligence(AI), or Deep Leaning, or Machine learning, or heuristic methods, or neural networks and other evolutionary algorithms, create intelligent solutions which prove that full automation is possible anytime in any environment [8] [9]. Benefits of deploying IoT in power systems include improved reliability, easy to resilient [10], improved adaptability, improved efficiency, less communication protocols, working in a networked environment and enhanced information handling capabilities, improved control on loads, provides on-request information access and enables client-provider service provisioning, higher sensing abilities, improved scalability and high interoperability, less reparations from natural disasters, and Reduced Power network physical attacks by endlessly running checks in real-time.

Considering the case study of this research which is University of Rwanda, College of Science and Technology, Agaciro Block, access to Electricity creates comfort zone for learning, conducting research, academic conferences, shows, sessions, conversations, restoration and leisure. In consideration of the stated roles of electricity, its cost gradually increases as new technological functions are deployed, being added to existing electricity consumption trend.
This research aims to deploy a fuzzy inference system controller built upon Fuzzy Logic rules basis. Fuzziness arises when we are in an environment of uncertainties, when there is no clear boundary or frontier. Throughout this research, it is not easy to have a single measure of the

electricity consumed by each load in a time, nor easy to conclude that the office or class is totally free, nor easy to conclude that any machine or appliance is not consuming electricity when it is always connected to the power source, hence deploying Fuzzy Logic will help in minimization of committing errors probability.

Fuzzy Logic shows a number of advantageous theories over other algorithms writing methods: more simplicity and flexibility, ability to manage and process inaccurate data, cheap for development, can cover all areas with instantly changing operating conditions, can work as human brain reasoning, very precise and can be used in the HVAC systems [11].
Through this research project, with the use of sensors, detectors, actuators, communication channels and cloud services, it is totally possible to monitor, control and access any environment from one point to another. With Machine learning and Artificial Intelligence algorithms, automation and prediction are done basing on recorded sensory data [8, 9].

Appliances and loads are chosen, then deployed based on their role, their effectiveness in delivering services, lifetime and power consumption characteristics. Each has its own consumption rate, and its way of being controlled and monitored. The functions of Heating and Cooling, Networking (servers and computers), machinery equipment, Drying, Melding, and Lights are the ones that Power Optimization Based on FIS and IoT 3 consume the huge amount of electricity. Electricity consuming loads are put in categories according to their consuming characters, "white goods" refers to a group of huge electricity consumers including electric refrigerators, heaters and ranges, butchery freezers, air conditioning systems, Laundry washing & drying machines, indoor house heaters and other electricity consuming commercial loads [12].

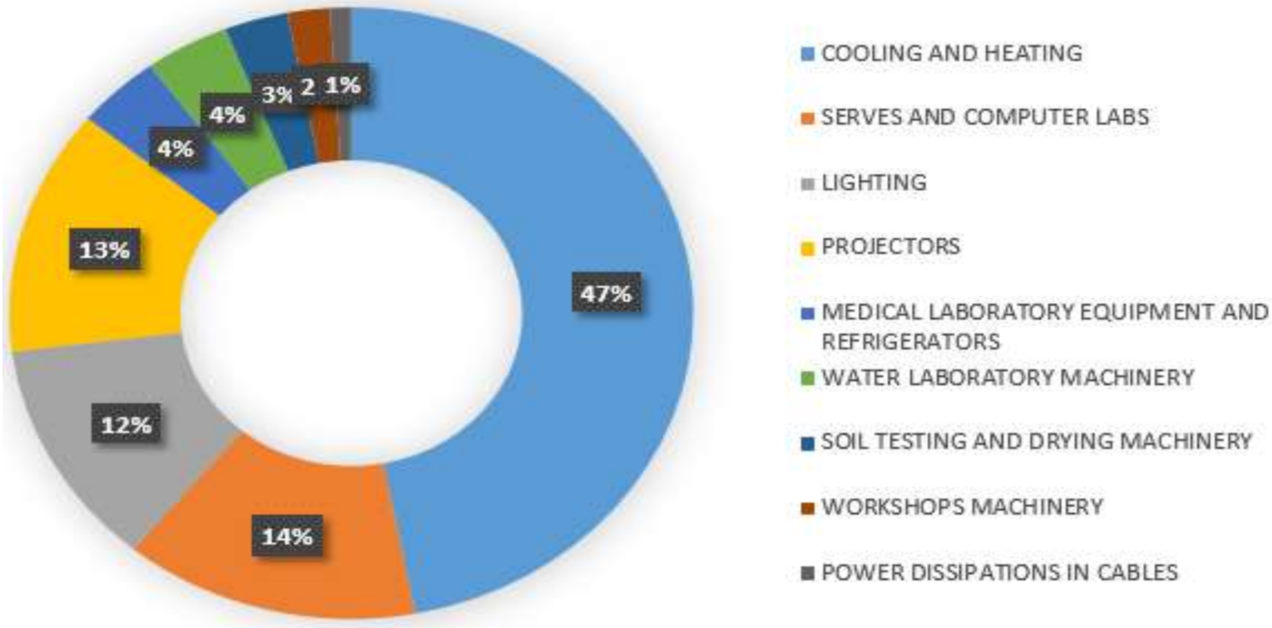

Figure 1 Electricity Consumption per category (Data from UR-CST Estate Manager)

Fig. 1 describes the consumption rates per each function and as the figure describes, functions of Cooling (Cooling systems) and heating takes maximum of the power consumption, followed by Server-room and computer labs, followed by Projectors and lights. It is clear that if there is optimization in these functions, will positively impact the overall power consumed, and positively will impact the overall cost spent in Power Consumption and Power Management Sector.

From the claim of repeated audits in Estate management concerning the increase in electricity usage, also the decrease of campus-holds machinery and equipment lifetime, increased cost of reparations, uncertain power failures in different blocks, the estate management team is looking for an effective and reliable way to face these issues

The team still uses the old traditional ways of power consumption management which includes surveys and site visits, theoretical data studies and analysis all of which still complicate the works of the Estate Management Team.

With the integration of IoT, the state-of-the-art, one of the newest technological concepts to face these issues, it is possible to shape and effectively minimize electricity power consumption, even predict the future consumption trends as different big data study and analysis algorithms appear.

Though many electricity and power management technics are being deployed, from power generation, power distribution and at the client usage side, it is still our core value to not misuse or mismanage sources, electricity should be used when there are people or known activities scheduled to be using it.

1.2 Motivation

As the university of Rwanda is still growing, there is much need of source of funds, one way is good management of the properties it already possesses, having an intelligent electricity optimization system will decrease power consumption in general, and the funds put in electricity consumption will be put in other resources for the university to go forward.

1.3 Problem Statement

Previous researchers modelled load monitoring techniques, and different incentives towards power management are introduced, the Electricity Real Time Pricing, the control of Demand Response DR, control of Energy Efficiency, studies and control based on Electricity Time of Use ToR[13], designing and implementing electricity smart meters of different models [14], however they seem non-intrusive as they do not show how to fully automate load control and monitor. The literature review misses a comprehensive algorithm which can work with existing buildings to optimize electricity usage, empower users outlining and electricity access reports, sleeping & activating loads on real-time and accurate basis).

In general, The Electricity Power infrastructure faces the following difficulties:

Incompatibility of Utilities: there is a great need of a common infrastructure that should be respected by both industries and manufacturers in order to minimize development time, minimize the price and increase the associativity and easy integration between IoT devices [15].

Lack of standards and codes*:* different international standards makers and providers are hugely deploying standards on different basis [16].

Safety and protection: The use of DC systems yield issues as ac protection uses the concept of "zero crossing" of the currents to interfere it.

Lack of commercial products: many commercial products/appliances are designed to work with ac power systems, therefore it is not an easy task to remodify them to work with residential dc systems, since additional modifications are made for them to be in \dc-ready “state [17].

The main and general focus of this research is to build an Electricity optimizing system which is intelligent to work on both supervised and unsupervised manner. Obtaining an answer for this question will minimize problems that raise from electricity misuse and the general work of technicians will be minimized (it will be easy to track non-working loads). The main and general focus of this research is to build an Electricity optimizing system which is intelligent to work on both supervised and unsupervised manner. Obtaining an answer for this question will minimize problems that raise from electricity misuse and the general work of technicians will be minimized (it will be easy to track non-working loads)

With the number of problems raising from electricity distribution and management in UR-CST, “uncontrolled and unreliable electric power consumption comes first as it is the main cause of huge price spent, hoping that finding a solution for it will save the corresponding government money in the area”. The margin of the total cost spent in Electricity and its reparation varies between Rwf 19 to 25 million per month (data from UR-CST Estate Manager)

Basing on data provided by UR_CST Estate Manager, the services and functions that consume high electricity include: The Cooling and heating takes 47% of energy use and Lighting takes 12% of energy use, where some of them suck power even when they are turned off, hence hereby wondering how to reduce wasted energy and money, some ordinary solutions enabled users to use manual Shut off and other uses the reminders but cannot solve this management problem.

Other appliances that contribute to the problem include digital cable or satellite DVRs, laptop computers, printers, DVD players, central heating furnaces, routers and modems, phones, gaming consoles, televisions, and microwaves.

1.4 Study Objectives

1.4.1 General Objective

The general objective of this research is to design and implement a Fuzzy Inference System Based Electricity Optimization System with fully automated IoT intelligent loads, a solution which will boost the optimization, efficiency and reliability in electricity consumption and its management through making the existing loads Smart (integration of sensors, actuators & communication modules).

1.4.2 Specific Objectives

- Literature reviewing, the existing solutions, the working of the available electricity consuming loads (Both Fluorescent and LED lights, Cooling Systems LCs, projectors, grinding machines, welding machines, melting machines, heating machines and other lab machinery)
- Designing a fuzzy inference system controller
- Simulating the designed fuzzy based solution
- Studying the results (compare the results with the ordinary ones) to prove the difference and effectiveness of the solution

1.5 Hypotheses

This complemented research system will help the UR-CST Campus Estate Manager to have full control over all loads from Lights, Cooling Systems to other machinery. Power usage will be minimized as the current system will be enhanced with intelligence to work in both supervised and unsupervised manners. The output of the optimization will be updated on the system dashboard created with Node –RED platform. Moreover, the overall amount spent by the campus management team will be minimized so that may be invested in other profitable functions for both students and staff.

1.6 Study Scope

In conducting this research:

- Only one building is considered: **Agaciro Block**, College of Science and Technology, University of Rwanda
- For simulation, Voltage to be measured is less than 25V

1.7 Significance of the Study

The deployment of intelligent energy management system based on IoT, will contribute and benefit in assisting and promote the minimization of energy and power usage starting from the available power system and infrastructure. With the deployment of Machine Learning Fuzzy Inference System, energy management become easier to be done in efficient manner.

1.8 Thesis Contribution

Deployment of the state-of-the-art technology (Fuzzy logics) in power management and consumption control, training the available power system to work under both supervised and unsupervised manners, he end-user can now have full control on the loads and monitor the end devices

1.9 Organization of the study

Chapter one: General Introduction:

This is the introductory chapter. It describes the background of the study, the problem statement, and the objectives of the study, scope of the study, significance of the study, project interest and the organization of the study.

Chapter two: Literature Review: this chapter clarifies the work done by other researchers towards energy and power management

Chapter three: Research Methodology: this chapter clearly shows the writer proposed methodology with all corners covered

Chapter four: System Design and Analysis: this chapter shows the prototype, corresponding data dashboard & serial monitor and how the installation of sensor nodes is done

Chapter Five: Conclusion, recommendation and future works: this chapter gives the conclusion of the study and give recommendations for the future researchers, and propose the future works

Appendix: this scripts containing the overall codes for the Arduino based prototype showing how the Fuzzy Logic was applied with the corresponding libraries' calling

Chapter 2 Literature Review

2.1 Introduction

Optimizing power, increasing user comfort and minimizing power misuses are the main reasons to conduct research in power optimization [18] other reasons include the design of real time power management system and intelligent system in the power network, decentralization of power management cloud services to run on fog layer and the introduction of prosumers (power generation by the loads in the middle of the grid) [19].

To have improved efficiency in end-user electricity demand response, techniques of prioritizing operations between peak electricity demand hours to non-peak hours throughout the day periods, consideration of behaviour change, the shift of operations (example of a washing machine) with respect to when the sun shine so that the devices are powered by their own solar panels, all of these implicated that the use of the heavy electricity consuming loads is directly put to day hours when electricity is available at high level [20].

On the other hand, well studied consumption models were used to train autonomous in-house demand response. These models can help in estimating the overall power demand needed by deploying bottom-up technique to study end-user energy usage behaviour, it means giving a perfect estimation of the total amount of energy to be consumed by controllable appliances.

As there are inventions of newly energy consumers, only deployment of schedules in consumption can help in sharing available power with new applications, which include the deployment of plug-in electric vehicles. The studies prove that available time-varying electric power pricing structure, together with huge adoption of autonomous power management systems, would cause repeated reflecting peaks through the indoor demand.

To solve the issues of these re-bounding peaks made among indoor appliances energy demands, new structures in pricing were introduced including Multi-TOU and Multi-CPP [21].

The problem of high power usage was resolved by using RECAP Model –a technique of Recognizing all connected consuming loads and Summarize and report their consumption rates on Real-time basis by using one (1) current Sensor. In this way, the overall power consumed in buildings was reduced. Deployment of sensing system to control and monitor power efficiency in indoor power system raised new research contests: monitor milieu usage, control devices, working together with smart power meters and interfacing with the power grid.

In a good way of minimizing power usage, identifying and analysing each consuming load individually in the building is the essential point to generate power alertness, on the other hand making more efficient of the available power resources [22].

Deployment of the old Thermostatic controlling system in appliances (TCAs) is still in a huge usage in electricity & power management market. With calibrating TCA thermostat settings, the loads with higher consumption demand are moved from the period of higher price to the periods with lower price cost estimation for lowering the peak load and lowering the cost [23].

With the introduction of Smart cities, a smart concept was introduced to help in counteracting issues of air pollution, traffic control, and efficiency in power & energy, a Smart Energy Management System was designed to identify home consuming loads with the introduction of hybrid Unsupervised Automatic Clustering Integrated with Neural-Fuzzy Classification (UAC-NFC) model composed of:

- integration of electricity smart e-meters, named smart sockets, which stay in dormant state in residential environments with uncertainties and becomes active only against non-intrusive appliances monitoring;
- a gateway made of a RISC computing Machine programmed to work with a ZigBee communication network;
- a cloud platform built to work upon the hybrid Unsupervised Automatic Clustering Integrated Neural-Fuzzy Classification model [24].

G. Bedi and his team designed a smart home environment system, smart means that the environment is equipped with sensors including ones of temperature and humidity, ones of lights, ones of pressure and PIR Motion sensors; the controlling system communicates through communication channels that may include Wi-Fi, Zigbee, Bluetooth, or LAN IPv6), controlling PDA’s that may include remote controller, Telephone, or tablet), and dashboard data visualization systems [25]. The integration of sensors impacts data fetching, interaction and action taking, self-adaptation capabilities to different residential loads available in smart home [26].

The key for smart home energy management system include IoT sensory technology, improved network connectivity, tiny on-chip size, more cost effective devices, easy to develop manufacturing, improved computational abilities, and advanced controlling systems.

IoT sensory system offers much benefits when integrated within smart residential environment. The methods help in minimization of energy wastage, contributes in reduction of costs, Real-time home environment monitoring, early detection of harmful environmental substances as carbon monoxide, radiating substances and harmful smoke. Life is made convenient and more comfortable with the integration of sensory systems and improved connectivity [27–30].

There are numerous types of IoT sensors that can be deployed in making smart environment:

2.2 Smart home people occupancy sensors

With the integration of occupancy sensors ex Passive Infra-Red PIR Motion Sensor, the owners is able to control any movements indoor and outdoor around, hence improves protection of the residential places from robbers and criminals. With these sensors, there is also the ability to control energy wasted in lighting the area according to people’s availability in the due environment.

In residential environments, different types of sensors can be used to detect occupancy, and they include perimeter sensors, motion PIR sensors, opening and closing sensors [31–33].

Motion & Movement detection sensors: They are the sensors that detect moves & circulations inside the house or in any environment. With their integration, motion sensors, the environment owners can monitor movements in the ground, moves of the pets or children to make sure that they do not pass “don’t-pass” regions, and monitor any presence of people in a distinguished environment, in this way it is also easy to have control over lights to light them on or off accordingly [31–33]. The motion can be detected by using PIR passive Infra-red, other detection sensors [34].

Open/close sensors: These sensors are there to detect any kind of open & close indoor or outdoor, these sensors can in return control the switch ON or OFF the corresponding lightings when the door or a window is opened or closed. [31–33] Examples of these sensors include glass breaking sensors, PIR sensors, door & window sensors [34,35].

Perimeter sensors: They sensors help in monitoring any approaching for example, something or someone trying to approach your vehicle or house [31–33].

Some types of the Perimeter sensors are radar sensors, fence, active infra-red sensors, vibration sensors, driveway, capacitance sensors, and electric field sensors [35].

2.3 Environment monitoring sensors

The smart environment type of sensors are the ones that create smart and more comfortable living environments, both indoor and outdoor of residential places [31]. Some types of smart environmental sensors are temperature & humidity sensors, leakage & water sensors, smoke detection and air quality sensors, and photo light sensors [33].

Temperature and humidity sensors: They sense any change in environmental heat, coldness, the amount of vapors in residential places, and indoor or outdoor temperature. These sensors help in minimizing energy wasted by controlling how cold or hot an area is. Whether there are people or not [31]. Some types of these sensors include DHT11 & 22 temperature sensors, bimetallic sensory devices, temperature resistive devices, Infra-red IR sensors, silicon diodes, thermocouples, change of state sensors and thermometers [36]. Some types of humidity sensory system include resistance & capacitance sensors [37].

Leakage and water flow sensors: They are the sensors that alert the residential places owners as leakage is detected, preventing damages of flooding which are often costly to recover from [31]. The types of leakage and water flow sensors are under-carpet leak detectors, hydroscopic-tape based sensors, rope style sensory systems and spot-leakage detectors [38].

Smoke detection & quality of air sensors: They are the type of sensors that screens and keep observing air quality indoor and outdoor of the residential places or outdoor environment. With smoke and air quality sensors, the owners of residential places are able to easily detect the smoke, CO- Carbon Monoxide and other types of risky gases inside or outdoor [31]. Hence, It enables full track on harmful gases and counterfeit measures are taken before any serious damage happens. Those types of sensors include ionization sensory systems, photoelectric sensors, dual sensors, projected beam sensors, aspirating sensors, video sensors, & heat sensor [39].

Light sensors: They keep monitoring the light levels indoor or outside of a residential place. They autonomously calibrate the light depending on the current sun lighting. [31] This lighting autonomy enhances the bulbs lifetime and save energy from wastages. Types of these sensors include photo junction diode sensors, photo-conduct sensors & photo voltaic sensors [40].

2.4 Power monitoring sensor

Smart home power monitoring sensors help in repeatedly monitoring the amount of energy consumed by each load indoor or outside of a residential place [31]. with the help of these power monitoring sensors, the owners can have full knowledge and notification of energy consumed by each load per unit time, fine-tune each load's power usage behaviour in order to overly minimize the cost & reduce overall energy wastage with assurance that residential loads and other appliances are functioning effectively and that they are not consuming much power. Among different types of power monitors: we have readout & history monitors, instantaneous readout monitors, plug-in monitors and circuit by-circuit measuring monitors enabled with history tracking & instant readout abilities [41].

2.5 Other sensors

For creating a smart home environment, there are other sensors that are trending in the market and include the followings [31,32]:

Dry contact sensors: they detect any contact between two wired points

Smart plugs Sensors: They enable home-owners to turn ON/OFF any home current consuming load or other residential places devices remotely by using control based PDA'(Ex. Smartphones).

Current transformer Sensors: they monitor the current flow indoor
of residential places or outside in the environment

AC& DC voltage sensors: they keep monitoring the power state of the power consuming loads and alert the home-owners when the voltage exceed the pre-set load consuming rates.

Power synchronizing sensors: they call and set autonomous triggers when there is a need to change the state of plugged in load (Ex. home owner can have the lights going ON in the room basing on the TV display light.

Other smart monitoring sensors: There are many other smart monitoring sensors that can be deployed, and that can work together with the above mentioned sensors when grouped and deployed in single sensor node. These kits provide the residential places & houses owners with an innovative and comparably not expensive way to control and stay in-line with the house overall activities from any location and any time. The other functionalities of these nodes can be improved by interfacing them with other compatible peripheral (Ex: cameras).

Table 1. lists types of sensors for Smart Home, provided with the leading manufacturers basing on the Market trends of Smart Home Applications [31,32].

Table 1 IoT Sensors for Smart Power Usage Management

Types of sensors	Main Manufacturers
IoT Occupancy Sensors:	
Motion Sensors:	Visonic, Optex, Hubbell Bryant
Open/Close Sensors:	United Security, Seco-Larm, Skylink Technologies
Perimeter Sensors:	United Security, Seco-Larm, Safety Technology International
IoT Environment Sensors	
Temperature & Humidity Sensors:	Minotaur Engineering, Winland Electronics, La Crosse Technology
Light Sensors	Woods, Intermatic, Minotaur Engineering
IoT Power Monitoring Sensors:	
Smart Plugs Sensors:	Insteon, Leviton, Zuli
Current Transformers Sensors (CTs):	Neurio, Panoramic Power
AC/DC Voltage Sensors:	Insteon, Global Cache
Power Synching Sensors:	P3 International, Electronic Educational Devices, Energy Inc
Other IoT Sensors:	
Dry Contact Sensors	Uptime Devices, Global Cache
Smart Home Monitoring Kits:	Samsung SmartThings, Notion, Nest, ConnectSense

The general limitations in the above literature is that they do not provide the full automated solution, one type of sensor cannot be used to effectively manage power consumption, there are more key actors and roles to consider for effectiveness.

The use of Fuzzy Inference System to build a smart powering management solution will provide a full automated and easy to run solution, easy monitoring and control over electricity power usage.

Chapter 3. Power optimization based on fuzzy inference system and IoT

3.1 Introduction

This research will deploy a Fuzzy Inference system controller FIS. FIS is chosen because its algorithm works in the environment of uncertainties, dealing with uncertainty coming from linguistic concepts without a clear boundary, it is not easy to have a single measure of the electricity consumed by each load in a time, it is not easy to conclude that the office or class is totally free, it is not easy to conclude that any machine or appliance is not consuming electricity when it is always connected to the power source, hence deploying Fuzzy Logic will help in minimization of committing errors probability.

Fuzzy Logic shows a number of advantages over other algorithms: more simplicity and flexibility, ability to manage troubles with non-precise data (with uncertainties), cheap for development, ability to cover huge area of operating conditions, work in conditions needing human reasoning, more precision and it is able to be used for the HVAC system.

Fuzzy Inference System Based IoT solution shows most of the ease as it will enable the Electricity management team to instantly detect any change (number of people, intensity of light, temperature & humidity in the environment, the presence of current & voltage, detection of vibrations), automatic way of put in active or sleep mode remotely, and predict the future electricity consumption demand.

3.2 The working of fuzzy inference system

There are 2 types of Fuzzy Inference System: Mamdani and Sugeno as described in Table 2.

Table 2 Fuzzy Inference System Categories

FIS	Description
Mamdani:	Instinctive, Compatible with human inputs Easy to interpret rules, The method won the wide approval
Sugeno:	Efficient computations, Easy to work with linear algorithms, ex.Proportional Integral Derivative controller, Intelligent in optimizing systems,Guaranteed outputs continuity, Good results with mathematical analysis functions

Throughout this research, a Mamdani FIS will be deployed, and to compute the Fuzzy Logics based Optimization by using Mamdani when given the inputs, the six steps have to be taken:

Defining & Setting fuzzy rules, Fuzzify inputs basing on the input membership functions, Multiplexing the fuzzified inputs basing on fuzzy rules to form rule strength, Getting the consequence of the settled rule by merging the rule strength and the output membership function, merging the consequences to get an output distribution, and Defuzzifying the overall system output.In general, Fuzzy Rules are built as follows: “if (input1 is membership people) and/ or (input2 is membership temphum) and/or (input n is member function n) then (outputn is output membership powerconsumed)”.

3.3 System components

This research work has 4 main parts:

A. **Sensors side:** Six different sensors are deployed: Occupancy PIR Sensors, Current Sensors, Voltage Sensors, Temperature & humidity Sensors, Light Sensors, and Vibration Sensors.

Table. 3 describes different sensors that are needed to accomplish the power optimization task. This research is considering Agaciro Block Building which has 4 Floors, each floor having offices, classrooms, laboratories and corridors.

Table 3. *Sensors needed in deploying this research work, their time of being active and Location of Deployment*

Sensors	Location of Deployment & Active time
Occupancy PIR Sensor:	Corridors, Laboratory, Conference room, Classrooms, and Offices (When Motion detected and timetables proves presence
Temperature & Humidity Sensor:	Laboratory, Conference room, Classrooms, and Offices (When people detected and timetable proves presence)
Current Sensors:	Server room, Laboratory, Conference room, Classrooms, Offices (Always ON for server room, when motion detected for the rest)
Voltage Sensors:	Server room, Laboratory, Conference room, Classrooms, Offices (Always ON for server room, when motion detected for the rest)
Light Sensors:	Server room, Laboratory, Conference room, Classrooms, Offices (Always ON for server room, when motion detected for the rest)
vibration Sensors:	Laboratories, Server room (Always ON)

- Current & Voltage sensors: are put on the power line feeding the room lights, power line feeding the sockets, power line feeding each computer lab, power line feeding the cooling systems – LCs, and line powering each laboratory of machinery & equipment and workshops, and these sensors are on the other hand connected on the Raspberry Pi Micro-controller, because this pi is able to deal with data from many sensors at the same time, and it is possible by enabling I2C mode for all sensors
- light sensors connected on each Light bulb
- Humidity and Temperature sensors connected in each office, room, class, corridors and halls
- Vibration sensors connected in each machinery & equipment lab and each clinic machinery
- Occupancy Sensors: installed in each room, office, class and halls

B. **Data Processing Microcontroller side:** ATMega Microcontroller is chosen for its numerous analogue ports and its flexibility towards small applications

To sense the presence of people and to count the number of people inside, two PIR Sensors are used, and the data is saved in a variable which keeps on updating as the number of people entering the room increases or decreases when they leave the room.

C. **Gateway** & **Data Transfer side:** Different communication channels are employed according speed, time, cost and flexibility (GSM/GPRS, Wi-Fi, LoRa and Sigfox)

ESP8266 with its built-in Wi-Fi is integrated in serial communication with the ATMega to enable the system to interact with the cloud applications through Wi-Fi and it makes it possible to establish a two-way communication with remote end- users.

D. **Cloud side:** the integration of cloud Dockers for further data processing and visualization by using NODE-RED based dashboards, data study and analysis, and storage for future use. The end users' Personal Digital Assistants i.e. Laptop, Smart phone, tablet fully connected on the internet, this simplify the works of the management team and increase the awareness in remote analysis of the loads and consumption rates to take measures where necessary

This research will bring a single solution to UR_CST Campus Electricity management, it will minimize electricity power consumption (starting from AGACIRO Block) in the loads as they will be turned into Smart ones, Consideration of timetables (scheduling the loads when to enter in active or sleep modes) in real time and providing this communication-enabled solution will ease the monitoring of the appliances through instant checks of both functioning and non-functioning loads.

3.4 Electricity distribution

UR-CST Campus has 5 Electricity Meters/ (Data from Estate Manager) and each has its corresponding feeding & consuming loads**:**

Electricity Meter 1 covers Dusaidi, Administration, both Restaurants, Kist1, Kist2, and Muhabura blocks

- Projectors, Lights inside, Road Lights (both LED based-18Watts and Fluorescent based40Watts)
- Soil testing Machineries, Water treatment Lab
- Lab for Machine tools: 4 machines with different power consumption rates: for mechanical

Electricity Meter 1 also covers the whole kist4 which has 4 Floors almost composed of laboratories, Physics Lab, Chemical Lab, Biological Lab all with a huge number of machinery, testing equipment, computers & fridges,

Electricity Meter 2 covers SABE: School of Architecture which has rooms having computing labs, plotting tools and other electricity consuming appliances,

Electricity Meter 3 feeds Library, FAED, Journalism(Projectors) and one tent in Akagera Tents, all of this having lighting bulbs, projectors in Journalism rooms, and LCs cooling systems in Tents Electricity Meter 4 feeds the whole uncovered part of Akagera tents, the appliances are Cooling Systems LCs, Road lights, Lighting bulbs inside, and Electricity Meter 5 covers the new part of former KHI: Clinics for Dentistry and Ophthalmology having Machineries and Medical Equipment, classes, offices, and hostels for girls which all consumes electricity.

The four floors of KIST1 (AGACIRO Block) and the distribution of campus functioning are described in Figure 2.

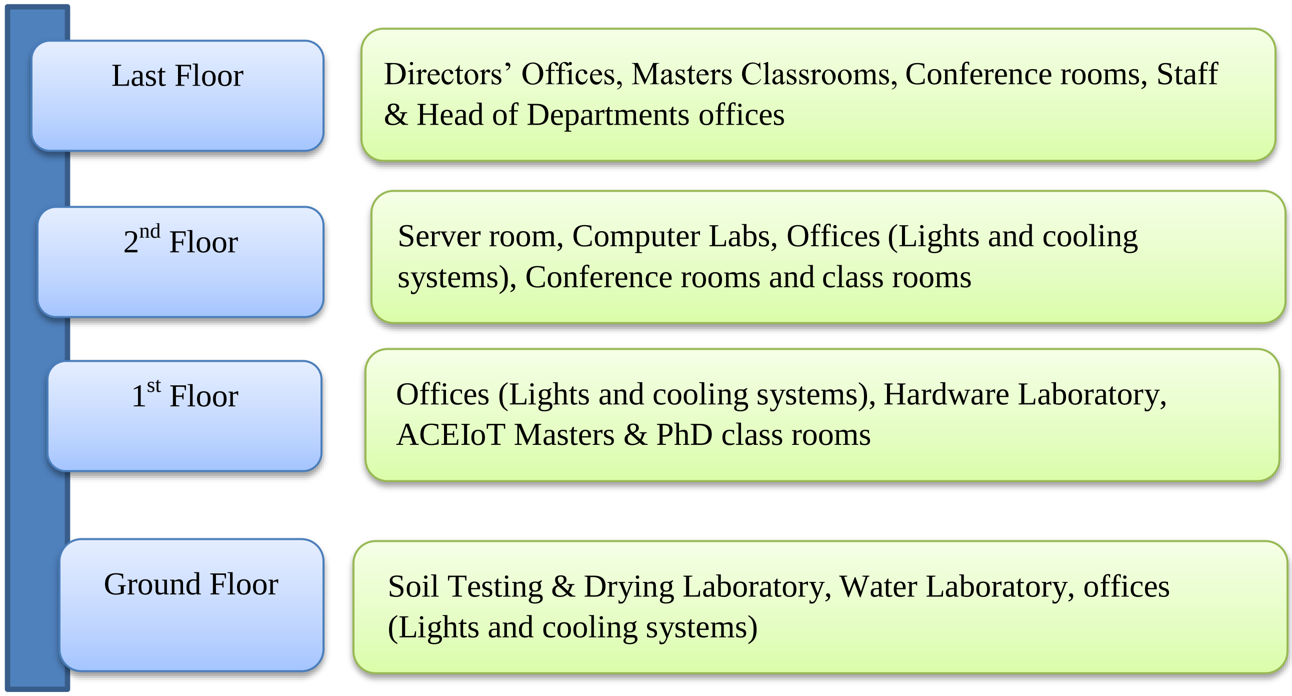

Figure 2 Functions as distributed in AGACIRO Block/ Data from Estate Manager

3.5 Sensors distribution

Table 3 describes the type of sensors, the locations where they will be deployed and corresponding time of being in Sleep or Active modes

Type of Sensors	Locations	When to be in Active Mode
Occupancy sensor	Corridors, Laboratory, Conference room, Classrooms, Offices	When Motion detected and timetables proves presence
Indoor & Outdoor Temperature sensor	Laboratory, Conference room, Classrooms, Offices	When people detected and timetable proves presence
current & Voltage sensor	Server room, Laboratory, Conference room, Classrooms, Offices	Always for server room, when motion detected for the rest
Light sensor	Building grounds, Labs, Classrooms, Offices, corridors	Always when motion is detected
vibration sensor	Laboratories, Server room	Always for server room and Labs when timetable proves the presence

Table 3 Type of sensors needed and corresponding locations

The figure 3 shows a block diagram of needed sensor nodes and corresponding allocation (each node is made of sensor, micro-controller, connectors, and a communication module which acts as a gateway)

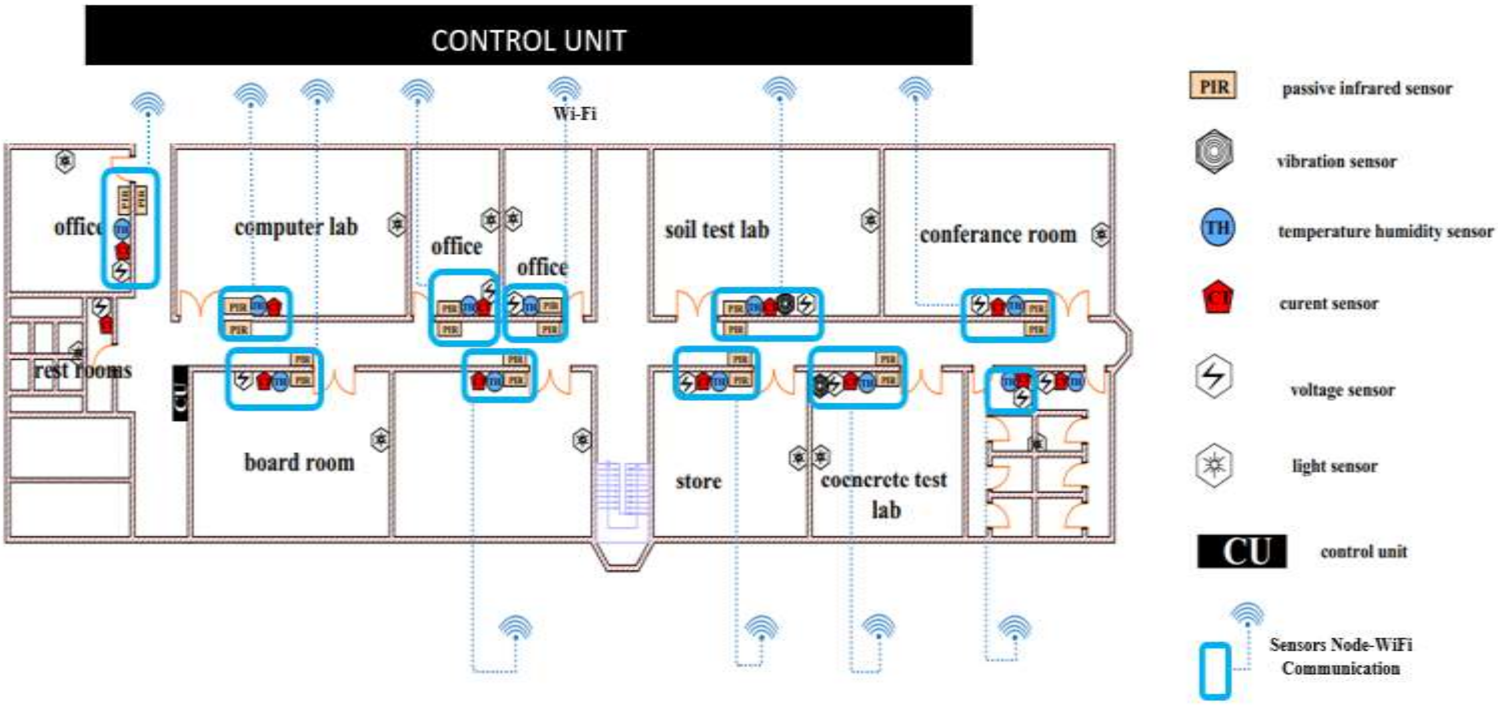

Figure 3 Block diagram of sensor nodes allocation

Figure 4 shows a simplified architecture of the proposed methodology, from the sensor nodes to Cloud, and from cloud to end user who controls and monitors the system through two-way communication channel

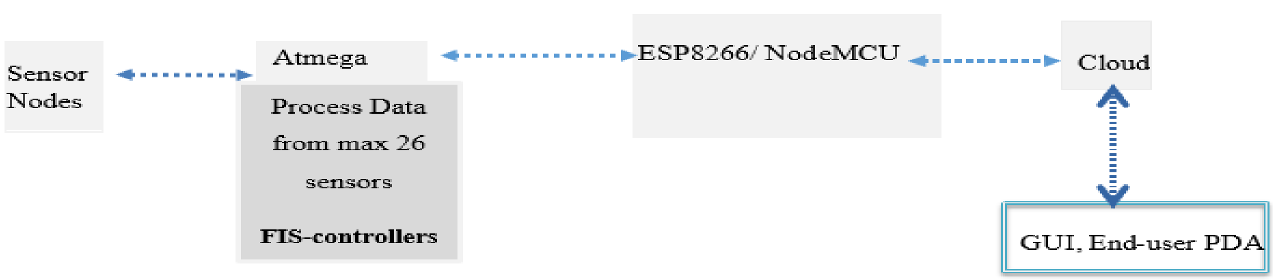

Figure 4 The general architecture of the FIS Based Electricity Optimization System

3.6 Applying fuzzy inference system

This part describes how the fuzzy inference system is deployed for controlling purposes.

3.6.1 Deployed system components

As Fig. 5 describes, the data sensed contribute to the computation of the overall power consumed per unit of time, which is optimized with the help of Fuzzy Inference System Arduino Libraries

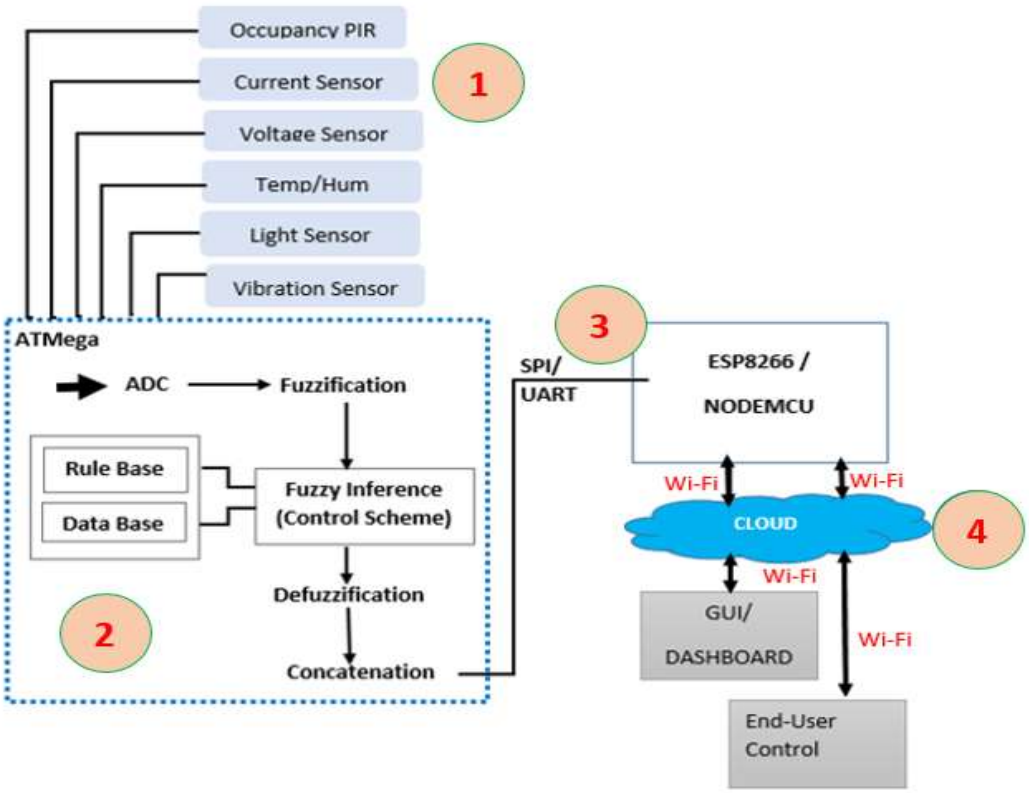

Figure 5 Fuzzy Rule Base Energy Monitor and Controller

The methodology deploys a system as drawn in figure 5,

first **part (1)** is made of sensors which are occupancy PIR sensor which detects any movement in its detection range as shown in figure 6, current sensor as shown in figure 7, voltage sensor as shown in fig 8, temperature and humidity sensor as shown in figure 9, light sensor as shown in figure 10 and vibration sensor as shown in figure 11.

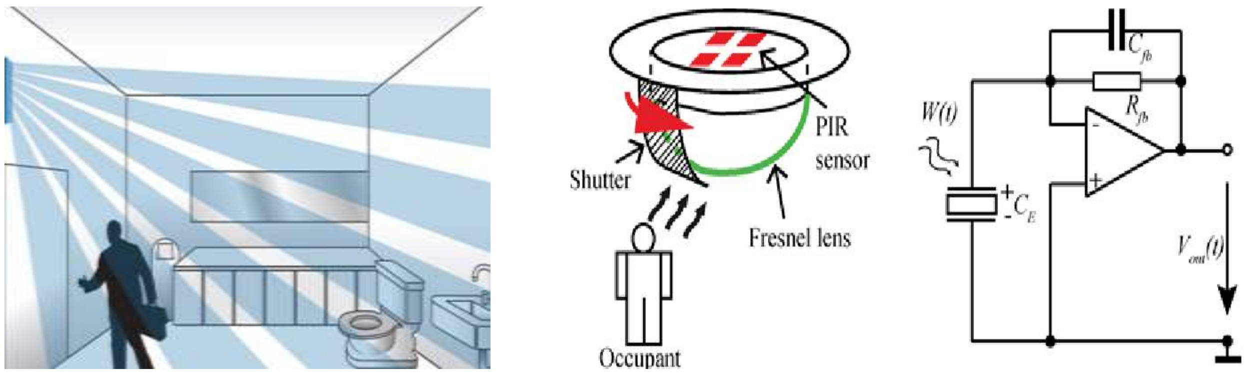

Figure 6 Passive infrared sensor PIR

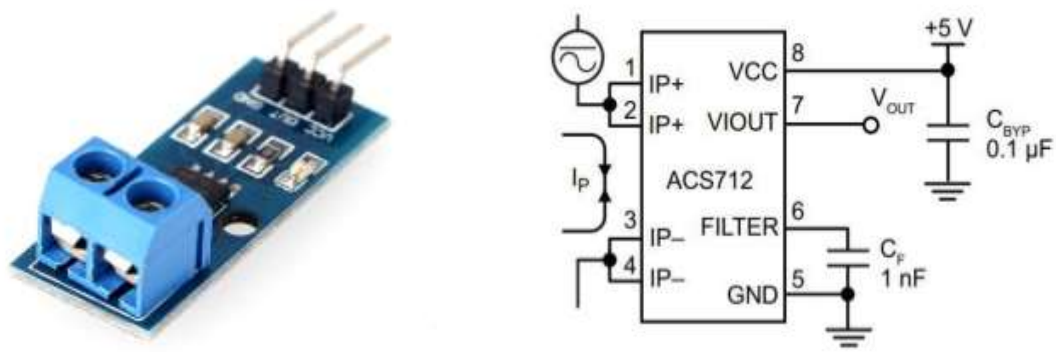

Figure 7 Current Sensor

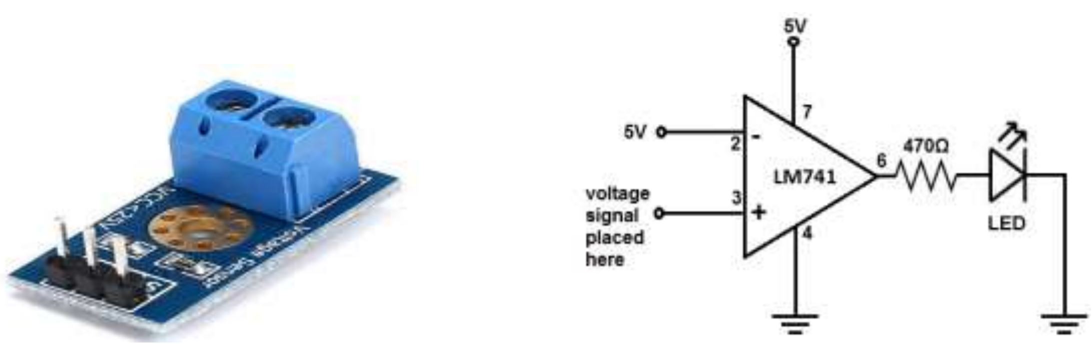

Figure 8 Voltage sensor

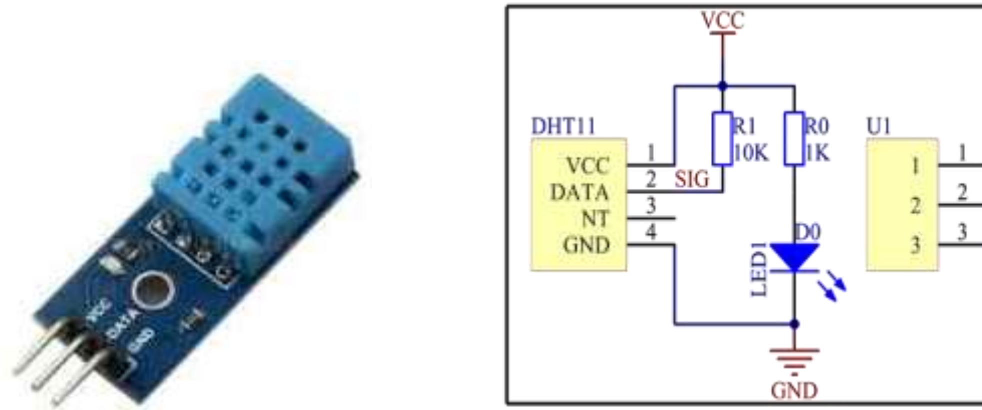

Figure 9 DHT 11 Temperature Humidity Sensor

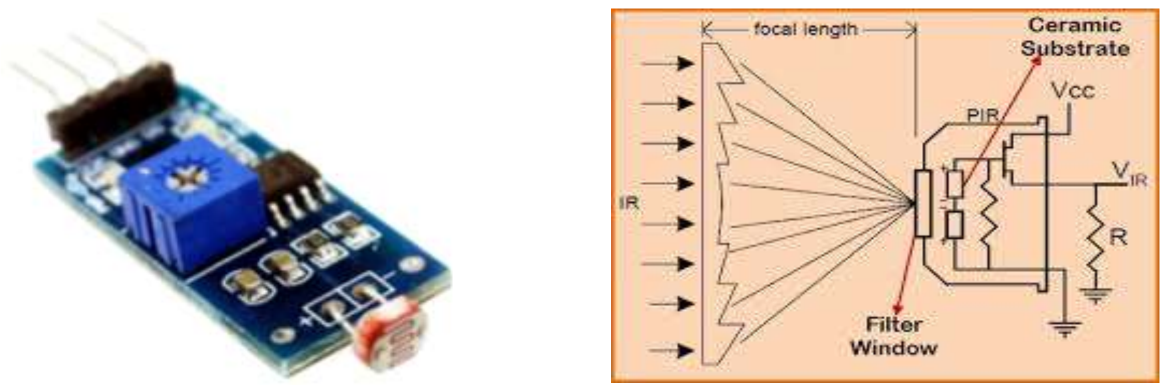

Figure 10 Light Sensor

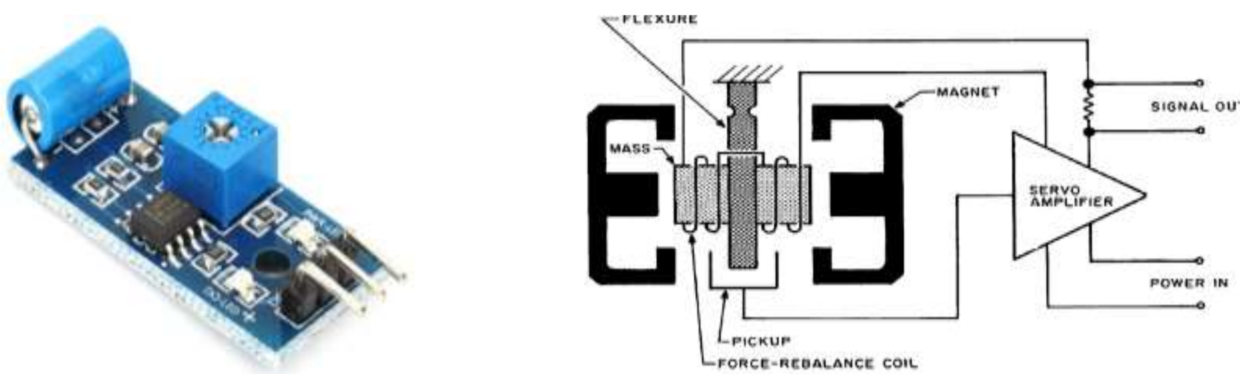

Figure 11 Vibration sensor

Second **part (2)** of the system is made of processing microcontroller which is ATMega board

Advantages of using Atmega: It runs on 5 V so legacy 5 V stuff interfaces cleaner; even though it's 5 V capable newer parts can run to 1.8 V. This wide range is very rare. Nice instruction set, very good instruction throughput compared to other processors (HCS08, PIC12/16/18). High quality GCC port (no proprietary crappy compilers). "PA" variants have good sleep mode capabilities, in micro-amperes. Well rounded peripheral set and QTouch capability.

Inside ATMega Microcontroller board, is defined the fuzzification process, creation of rules and data, defuzzification process, concatenation process and SPI/UART communication is enabled.

The general working of Fuzzy logic is explained as follow:

There are two types of FIS: mamdani and sugeno, this research is deploying only a mamdani based FIS.To compute the output of a **Mamdani FIS** given the inputs, the six steps have to be taken: (figure 6 gives more details)

- determining a set of fuzzy rules
- fuzzifying the inputs using the input membership functions,
- combining the fuzzified inputs according to the fuzzy rules to establish a rule strength,
- finding the consequence of the rule by combining the rule strength and the output membership function,
- combining the consequences to get an output distribution, and
- defuzzifying the output distribution (this step is only if a crisp output (class) is needed). [42]

The Figure 12 gives the more detailed description:

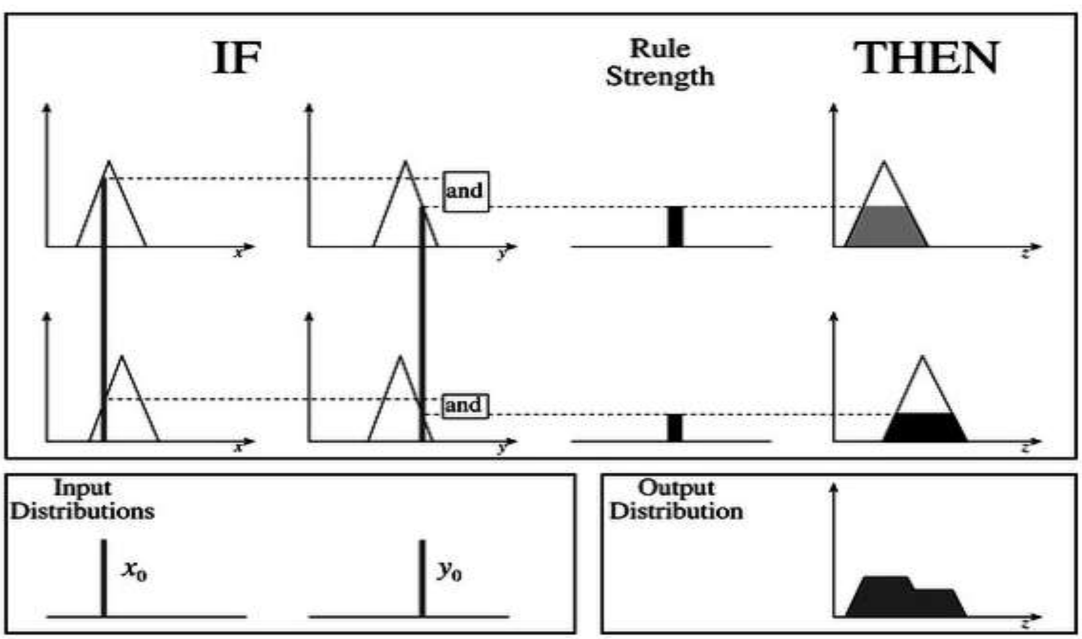

Figure 12 A two input, two rule Mamdani FIS with crisp inputs

Part (3) of the system describes the communication channel of data transfer from Atmega to ESP8266 Nodemcu**,** this is a serial communications enabled through the SPI Arduino library.

Part (4) of the system describes the wireless communication created between the ESP8266 Nodemcu and the Cloud, there different Virtual Private Servers where we can choose to send our data and different system integrations for data visualisation and feed backward enabling control system.

Chapter 4 System prototyping and experimental results

4.1 Introduction

To design the proposed methodology, an IoT prototype is built with the integration of Fuzzy Logics libraries in Arduino, fig. 14 is captured to show the prototyping of the proposed methodology.

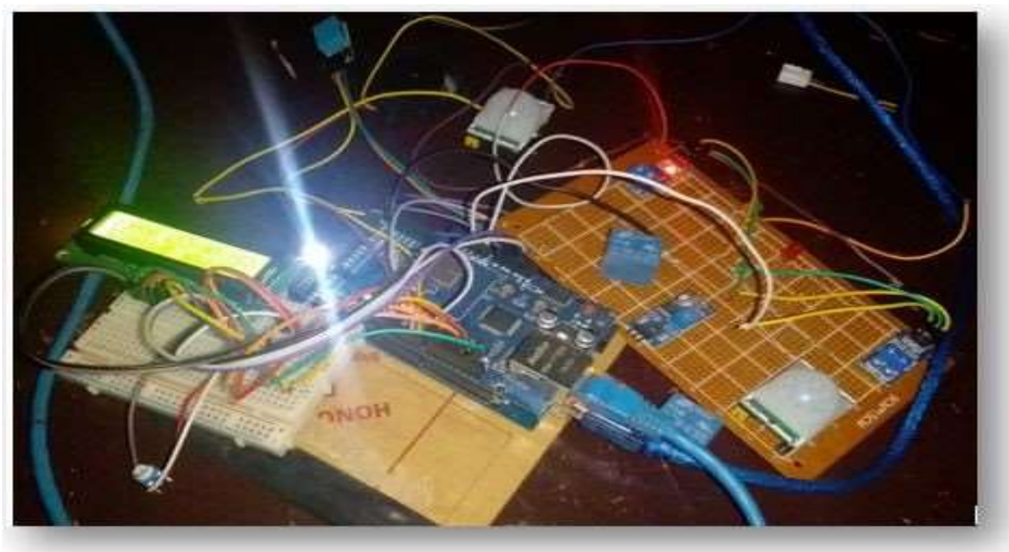

Figure 13 Prototype of the Power Optimization System with Fuzzy Inference System

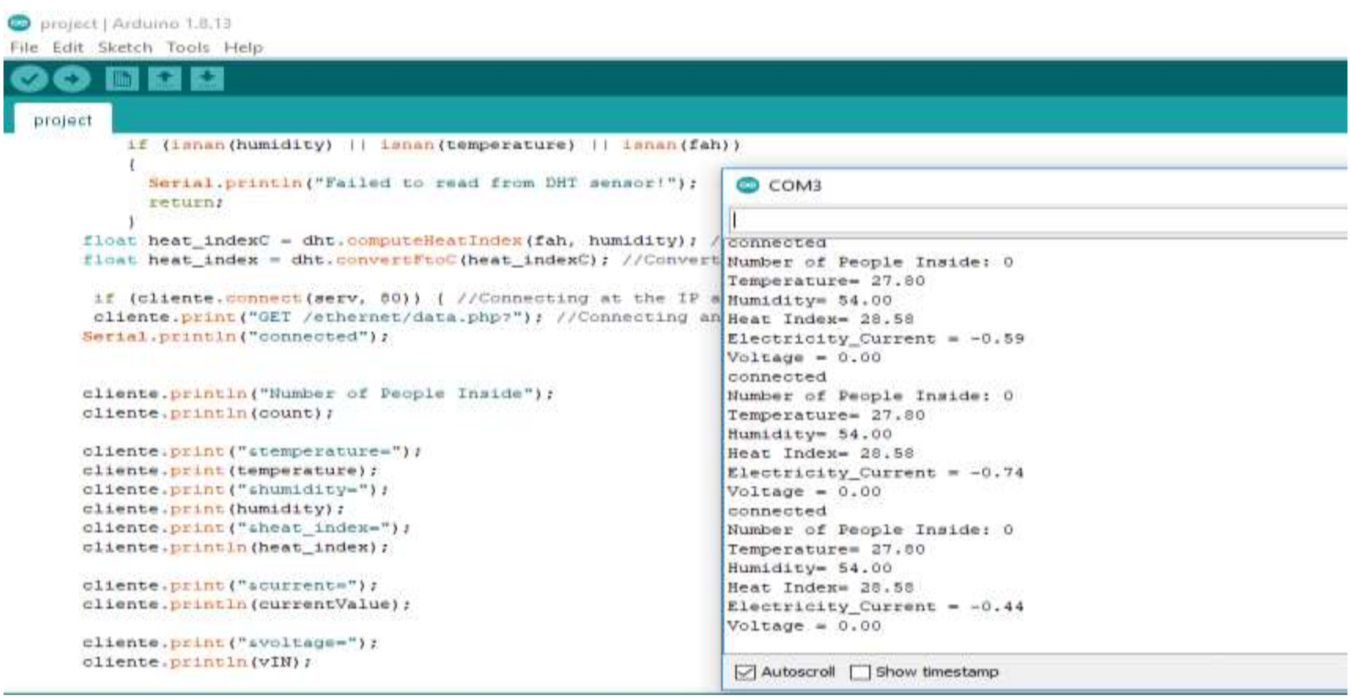

Figure 14 Arduino codes for the proposed methodology

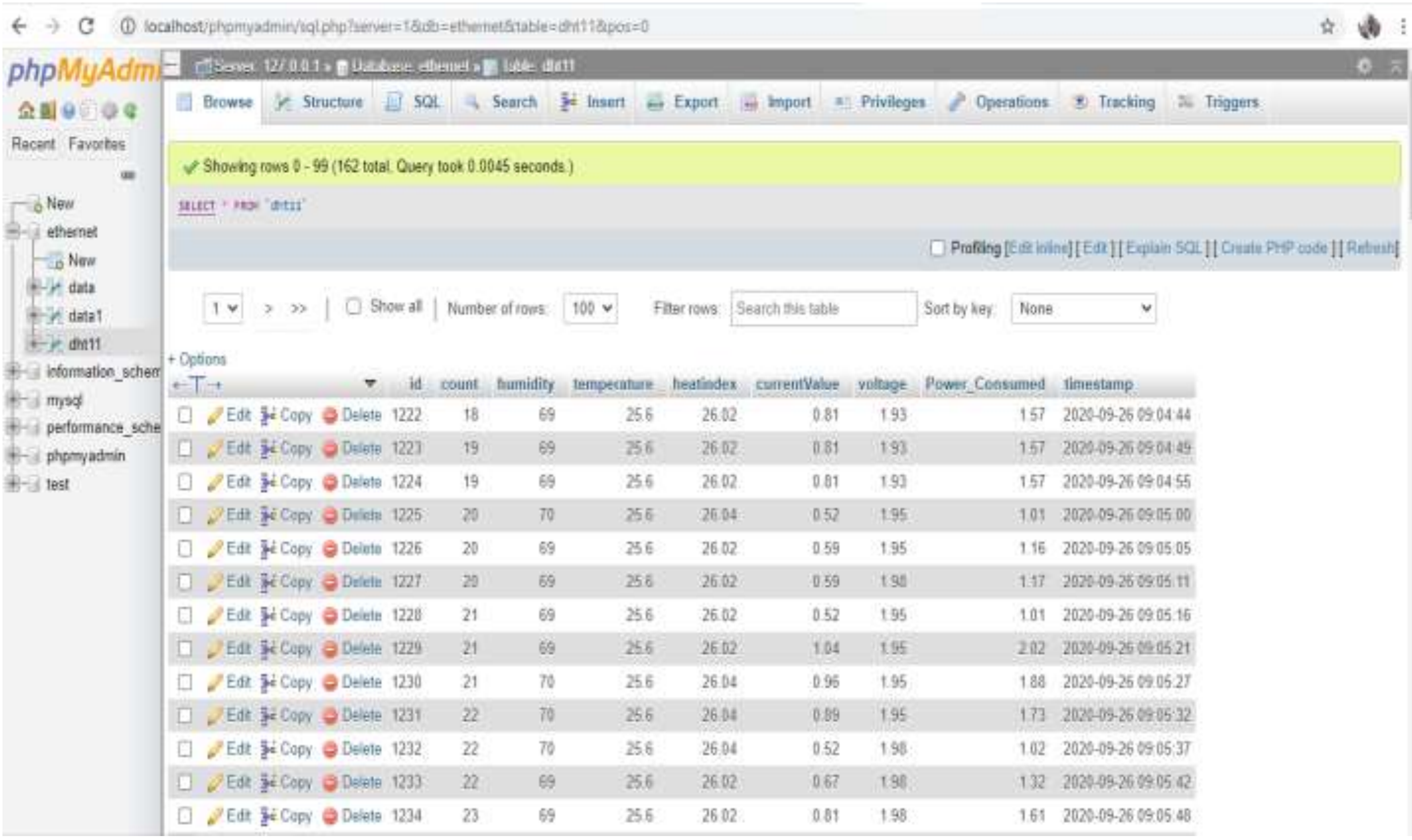

Figure 15 Database view of the proposed methodology

Fig. 15 and Fig. 16 shows both of the Serial Monitor solution display and corresponding MySql Database

For Simulation, we consider a Power Optimization function as Transfer function with variable s, Fig. 17 describes the SIMULINK of the Power Optimization function without fuzzy Controller, the transfer function in S is applied to shape the signal to be viewed with the Simulink Scope.

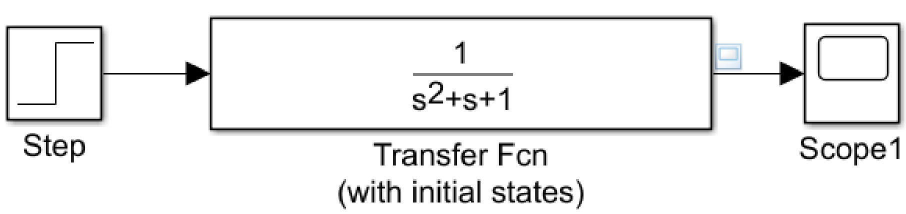

Figure 16 The SIMULINK Block diagram of the Power Optimization System without

4.2 Simulation results for signal strength

In Simulink, as the step input is fed to the transfer function, the signal strength shapes as shown in Fig. 18

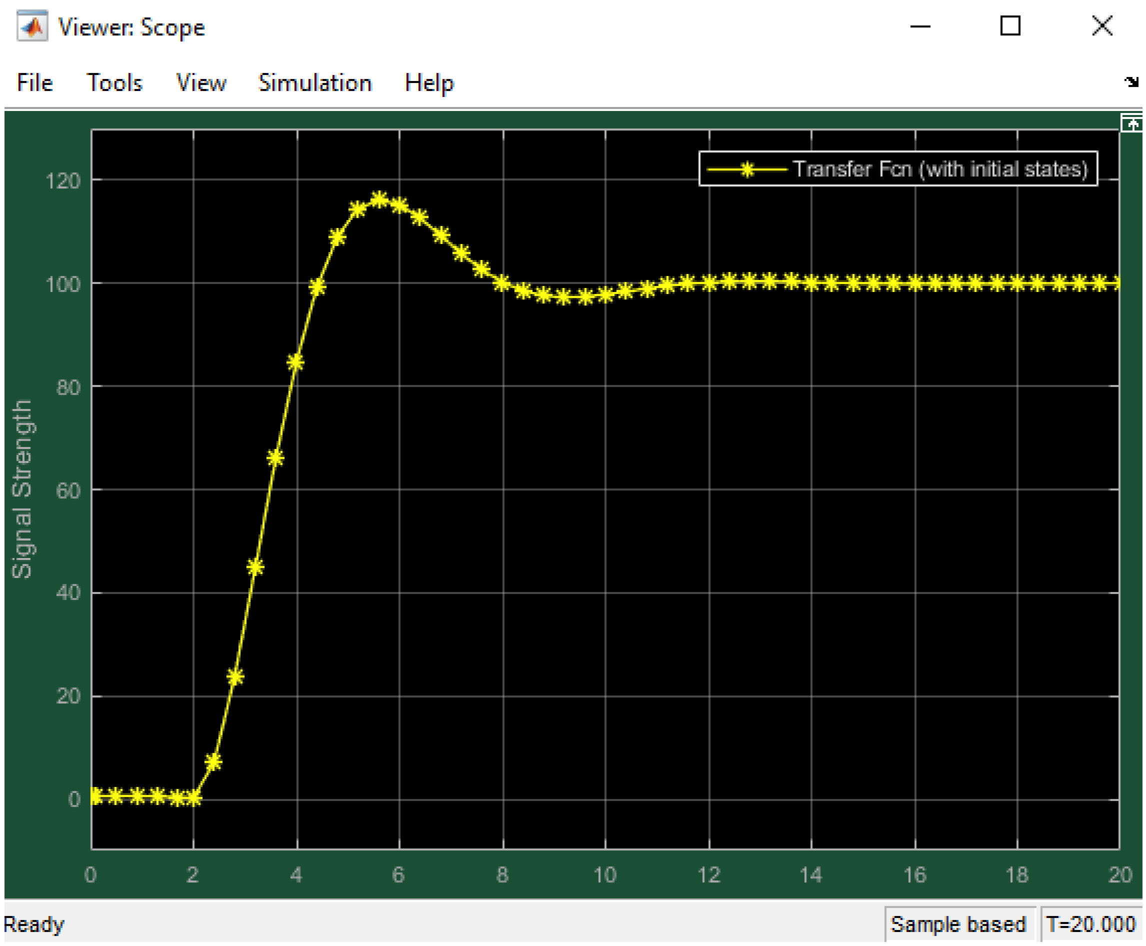

Figure 17 The Step Response of the Power Optimization System without Controller

The defined step block generates a step between two 0 and 100, step time 2, and sample time 2. The Fig. 18 describes the step response of the Power Optimization System without controller, the signal strength is zero for the starting time and it starts to go up from T=2, and it reaches high as the power consumption is not yet optimized, no fuzzy controller presents.

The following are the Simulink codes for the proposed fuzzy logics

[System]

Name =”ProjectFis”

Type=’mamdani’

Version=2.0

NumInputs=2

NumOutputs=1

NumRules=3

AndMethod=’min’

OrMethod=’max’

ImpMethod=’min’

AggMethod=’max’

DefuzzMethod=’centroid’

[Input1]

Name=’people’

Range=[0 8]

NumMFs=3

MF1=’few’:’trimf’,[0 2 4]

MF2=’average’:’trimf’,[2 4 6]

MF3=’many’:’trimf’,[4 6 8]

[Input2]

Name=’temp/hum’

Range=[8 40]

NumMFs=3

MF1=’low’:’trimf’,[8 13 18]

MF2=’moderate’:’trimf’,[18 23 27]

MF3=’hot’:’trimf’,[27 33 40]

[Output1]

Name =0 powerconsumption0

Range=[0.001 150]

NumMFs=3

MF1=’low’:’trimf’,[0.001 22 44]

MF2=’average’:’trimf’,[44 70 90]

MF3=’high’:’trimf’,[90 120 150]

[Rules]

1 1, 1 (1) : 2

3 3, 3 (1) : 2

3 0, 2 (1) : 2

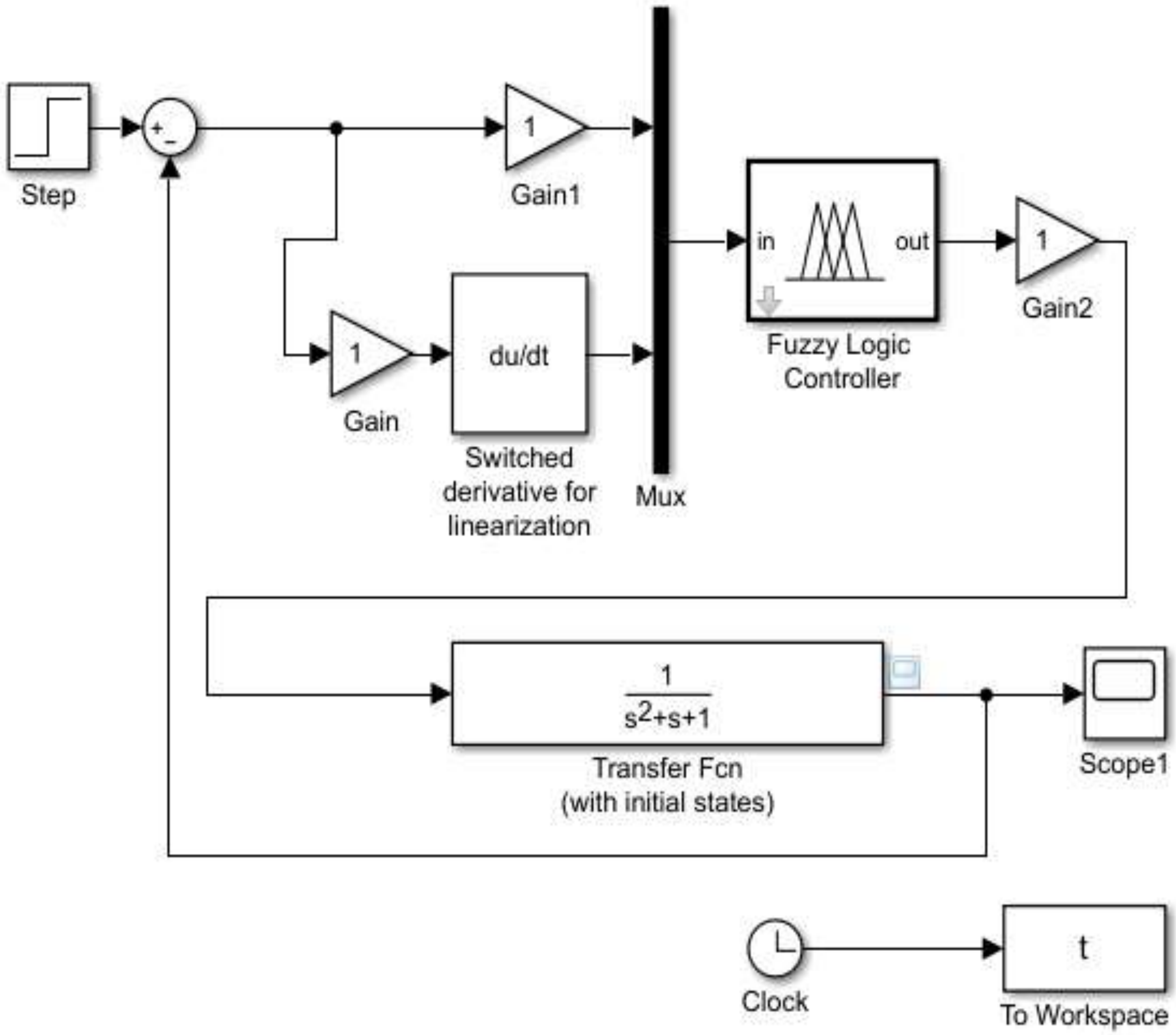

Figure 18 The SIMULINK Block diagram of the Power Consumption with Controller

Fig. 19 describes the SIMULINK block diagram of the Optimized Power Consumption System, under the working of Fuzzy Logic Controller. The Fuzzy Logic Controller is fed by the'ProjectFis.fis file', with the codes as described above.

4.3 Simulation results of optimized signal strength

As the fuzzy logic codes are fed to the Simulink block, the signal strength changes, ans the step response is shaped as described in fig. 20

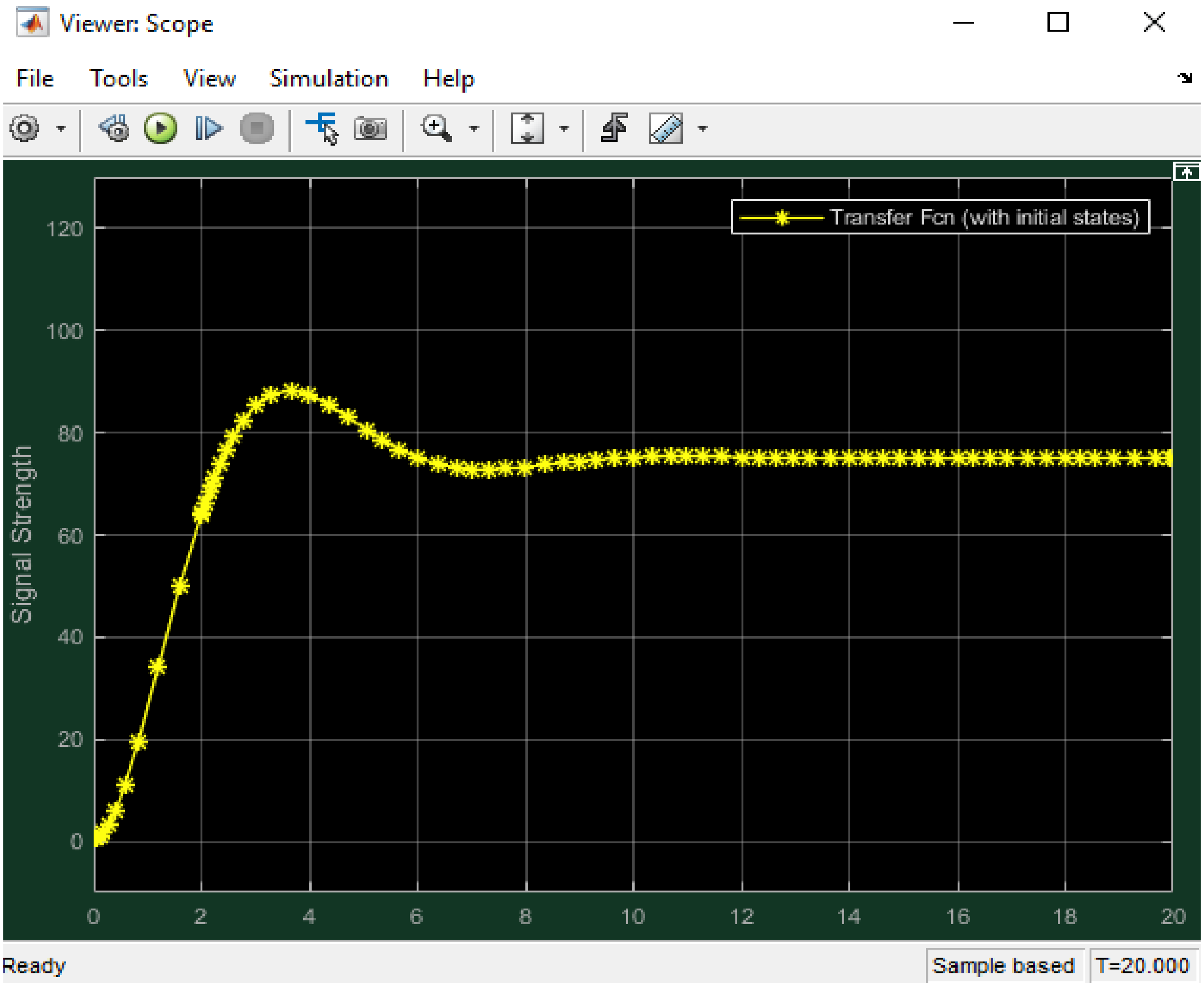

Figure 19 The Step Response of the Power Optimization System with Controller

Fig. 20 describes the step response of the optimized power consumption/ under control of fuzzy logics controller. The signal strength starts to go up directly from T=0, and as the maximum peak signal strength do not go beyond 85, it is clear that there was optimization from the added fuzzy control block, the figure shown above clearly explains the difference.

4.4 Simulation result for the whole room

After Simulation, the overall room fuzzy logic system is modelled as described in Fig. 21, the machine learning models the future consumption rates, and it makes the exact or approximate amount of power that should not be exceeded as there is an increase or decrease in inputs (room occupancy and temperature & humidity of the room).

Overall power is controlled and will be optimized each time there is a change in:

- **ambient room temperature & humidity**, as the system in its autonomic functioning tries to regulate and behaves accordingly to regulate temperature and humidity of the room, by turning ON/OFF the Cooling systems, heaters and lights
- **room People Occupancy**, as the system tries to provide at optimum

level all functions needed in the room with respect to the comfortability of people inside the room and appropriate and minimized power consumption. The SIMULINK codes provided above with the title System=ProjectFis.fis contains the fuzzy controlling rules which yields the Fig. 16 when compiled and run, the overall power optimization will depend on the number of People in the room, the Temperature and Humidity of the room, Lights, and other consuming loads connected.

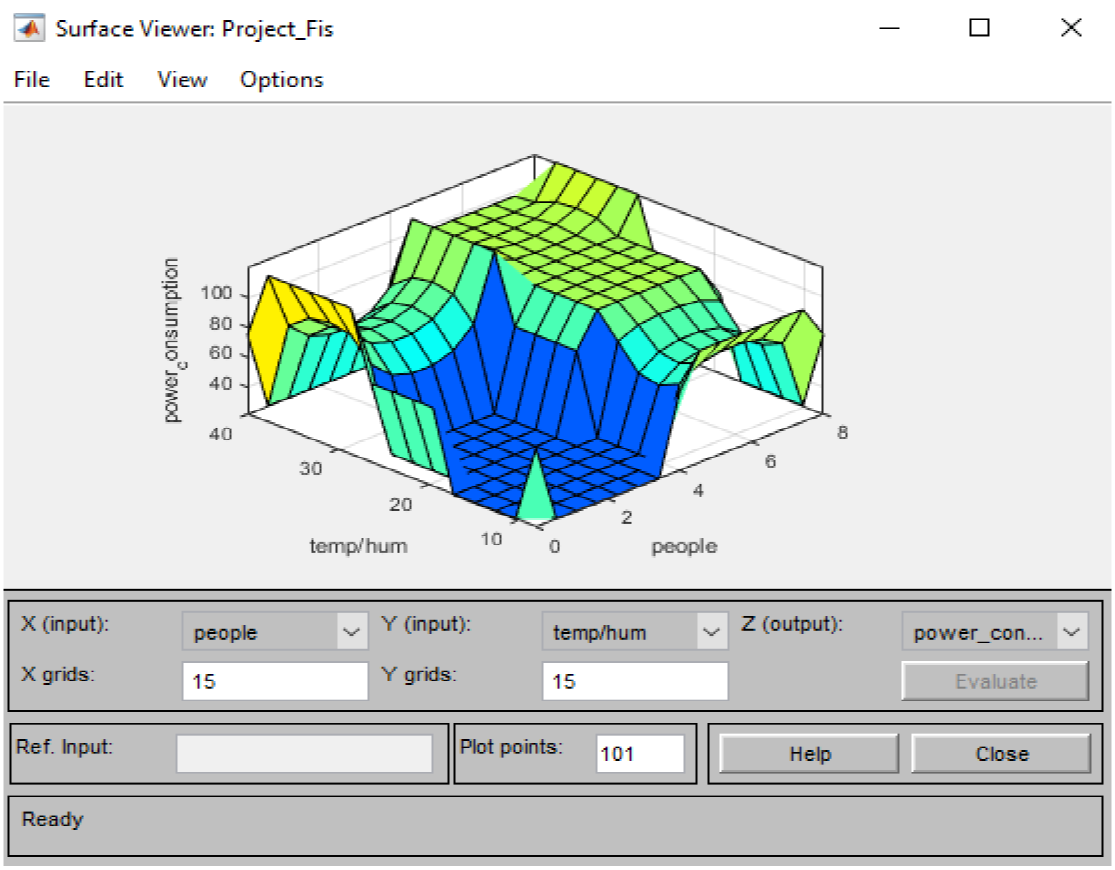

Figure 20 Power Optimized basing on room Temp/Hum and Room Occupancy

Fig. 22 & Fig. 23 clearly defines the Fuzzy Rules Views of this research, the following is the explanation: When the room occupancy is 1 and less than or equal to 3, and the room temperature is normal, the power optimization is at lowest level because there is less need of improving the overall room comfort, When the room occupancy is greater than 3, and the room temperature is normal, the power optimization is at moderate level because there is need of improving the overall room comfort by controlling the room temp/hum, and other functions which need access to power. When the room occupancy is high or temperature is high, the optimization is at the highest level.

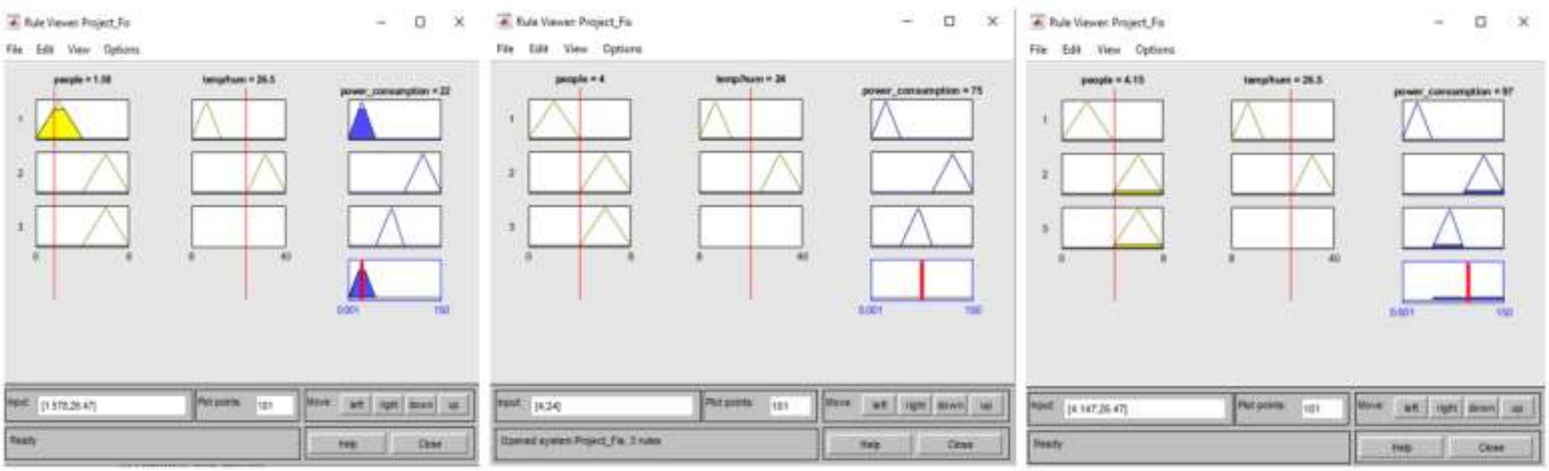

Figure 21 The Fuzzy Rules Viewers

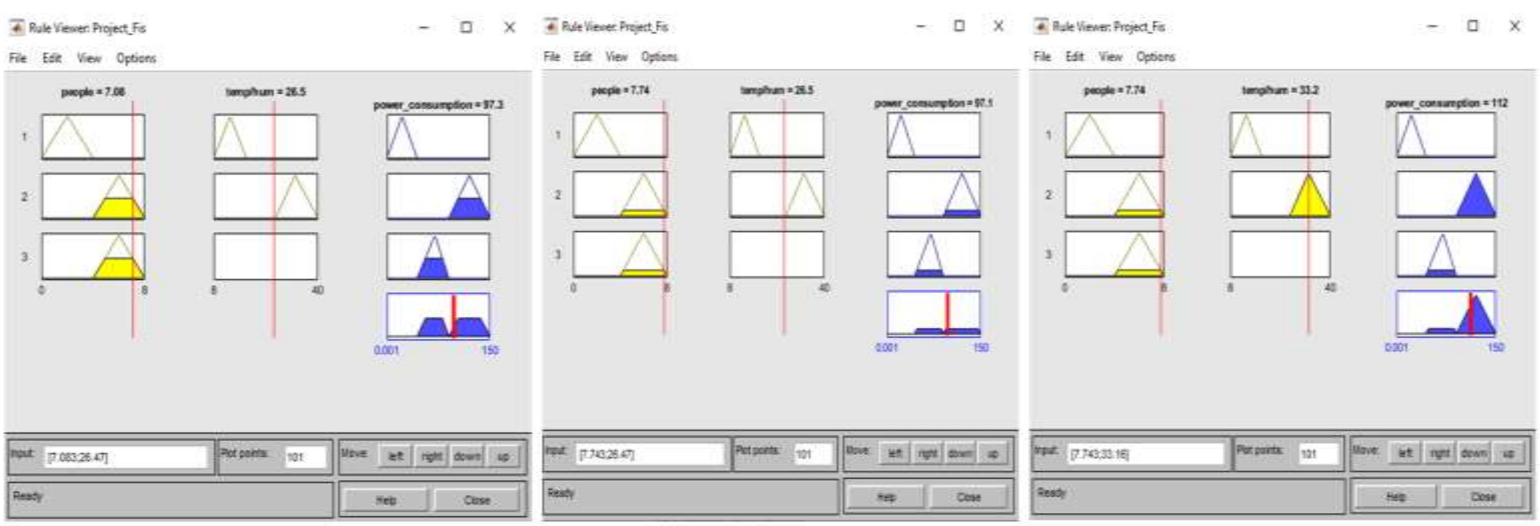

Figure 22 The Fuzzy Rules Viewers

4.5 Data visualization

The result of the proposed methodology is displayed in the following fig24. Which shows all instantly data of the room? Total number of people inside the room, current optimized temperature of the room, current humidity of the room, hourly rated power consumed by lights, hourly rated power consumed by projector, and hourly rated power consumed by other loads connected on the same power line.

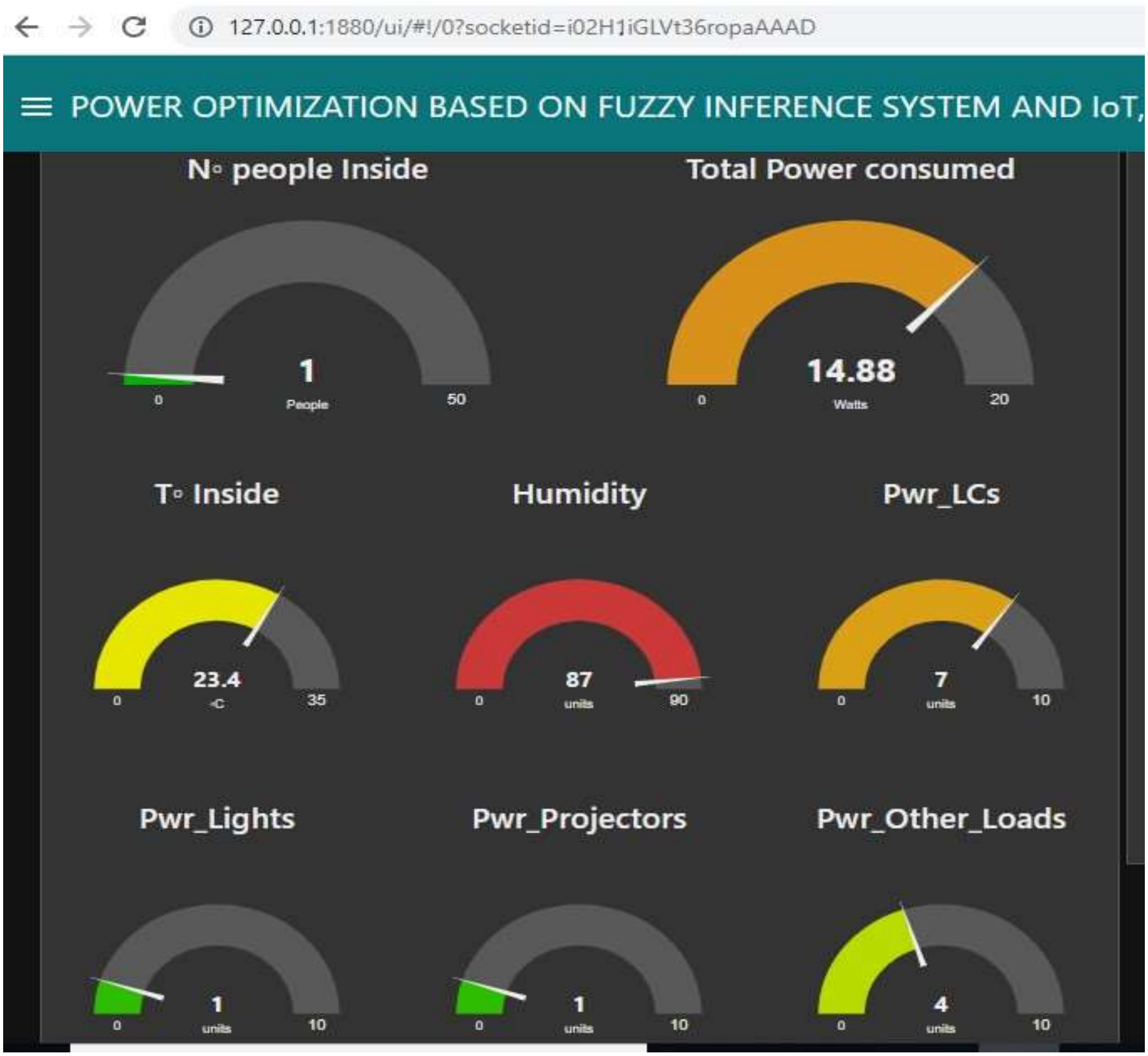

Figure 23 The Dashboard and Monitoring UI

Chapter 5 Conclusion, recommendation and future works

This research project aimed at optimizing electricity usage in university of Rwanda, college of science and technology, mainly considered Agaciro block building single room, and the methodology was deploying a fuzzy logic controller to work together with Internet of Things sensory system. Based on the results of prototyping and simulation results, it is clear that Fuzzy Logics applied has played a vital role in optimizing Power. The overall power is optimized as there are optimizations in power consumed in major functions: Cooling and heating, projectors, lights and labs machinery. In the near future, Efficiency in power management systems will be a must for eliminating the issue of Electricity shortage in nations. There is no doubt that the continuous electricity usage control need to be continuing, and all possible measures have to be taken to optimize available energy resources.

Recommendation: I recommend that this project be implemented in UR-CST Campus so that the overall power consumed will be minimized.

Future works: This project should be extended to other buildings; also deployment of other machine learning algorithms to increase the overall power system performance in the campus.

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Appendix 1 Project Arduino codes

```
//POWER OPTIMIZATION BASED ON FUZZY INFERENCE SYSTEM AND IoT, CASE STUDY OF UNIVERSITY OF RWANDA - COLLEGE OF SCIENCE AND TECHNOLOGY - AGACIRO BLOCK BUILDING

//DONE BY JEAN LOUIS NIRAGIRE, REF: 215030228


#include <FuzzyRule.h>

#include <FuzzyComposition.h>

#include <Fuzzy.h>

#include <FuzzyRuleConsequent.h>

#include <FuzzyOutput.h>

#include <FuzzyInput.h>

#include <FuzzyIO.h>

#include <FuzzySet.h>

#include <FuzzyRuleAntecedent.h>

#include "DHT.h"

#include <SPI.h>

#include <Ethernet.h>

#include <LiquidCrystal.h>

#include <LiquidCrystal_I2C.h>

LiquidCrystal lcd(8,9,10,11,12,13);  // set the LCD address to 0x27 for a 16 chars and 2 line display

byte mac[] = { 0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED }; //Setting MAC Address

#define DHTPIN 2

#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);

//byte mac[] = { 0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED };

byte ip[] = {192,168,10,10}; //Enter the IP of ethernet shield

byte serv[] = {192,168,10,2} ; //Enter the IPv4 address

EthernetClient client;

float humidity;

float temperature;

float fah;

float heatindexC;

float heatindex;

float voltage;
```

```
float currentValue;

float Power_Consumed;

const int currentPin = A0;

float sensitivity = 66;

float adcValue= 0;

float offsetVoltage = 2500;

float adcVoltage;//float currentValue = 0;

//float Power_Consumed;

const int voltageSensor = A2;

float vOUT = 0;

//float voltage = 0;

float R1 = 30000;

float R2 = 7500;

float value = 0;

int count=0;

int entrance=6;

int entrance_value;

int exiting=7;

int exiting_value;

int a,b;

int tot_after_entering=0;

int tot_after_exiting=0;

int fan = 4; // the pin where fan is connected


//Instantiating an object library

Fuzzy* fuzzy = new Fuzzy();

// fuzzy vars

float err=0,derr=0,lasterr=0,fout=0;

void setup(){

pinMode(28,OUTPUT);

 pinMode(entrance,INPUT);

 pinMode(exiting,INPUT);

 pinMode(fan,OUTPUT);

  pinMode(currentPin,INPUT);

  pinMode(voltageSensor,INPUT);

  Serial.begin(9600);

  dht.begin();

  if (Ethernet.begin(mac) == 0) {

  Serial.println("Failed to configure Ethernet using DHCP");

  Ethernet.begin(mac, ip);

  }
```

```
 lcd.begin(16,2);
// Print a message to the LCD.
  lcd.print("FIS-PWR OPTIMIZE");
  lcd.setCursor(0,1);
  lcd.print("CS: UR-CST AGACIRO B");

  // Instantiating a FuzzyInput object
  FuzzyInput *people = new FuzzyInput(1);
  // Instantiating a FuzzySet object
  FuzzySet *few_people= new FuzzySet(0, 20, 20, 40);
  // Including the FuzzySet into FuzzyInput
  people->addFuzzySet(few_people);
  // Instantiating a FuzzySet object
  FuzzySet*average_people=new FuzzySet(30, 50, 50, 70);
  // Including the FuzzySet into FuzzyInput
  people->addFuzzySet(average_people);
  // Instantiating a FuzzySet object
  FuzzySet*many_people=new FuzzySet(60, 80, 80, 80);
  // Including the FuzzySet into FuzzyInput
  people->addFuzzySet(many_people);
  // Including the FuzzyInput into Fuzzy
  fuzzy->addFuzzyInput(people);
  // Instantiating a FuzzyOutput objects
  FuzzyOutput*power= new FuzzyOutput(1);
  // Instantiating a FuzzySet object
  FuzzySet * low_power= new FuzzySet(0, 10, 10, 20);
  // Including the FuzzySet into FuzzyOutput
  power ->addFuzzySet(low_power);
  // Instantiating a FuzzySet object
  FuzzySet*average_power=new FuzzySet(10, 20, 30, 40);
  // Including the FuzzySet into FuzzyOutput
  power->addFuzzySet(average_power);
  // Instantiating a FuzzySet object
  FuzzySet *high_power = new FuzzySet(30, 40, 40, 50);
  // Including the FuzzySet into FuzzyOutput
  power->addFuzzySet(high_power);
  // Including the FuzzyOutput into Fuzzy
```

fuzzy->addFuzzyOutput(power);

// Building FuzzyRule "IF people = few_people THEN power = low_ power "

// Instantiating a FuzzyRuleAntecedent objects

FuzzyRuleAntecedent *iffewpeople = new FuzzyRuleAntecedent();

// Creating a FuzzyRuleAntecedent with just a single FuzzySet

iffewpeople ->joinSingle(few_people);

//Instantiating a FuzzyRuleConsequent objects

FuzzyRuleConsequent *thenlowpower = new FuzzyRuleConsequent();

// Including a FuzzySet to this FuzzyRuleConsequent

thenlowpower ->addOutput(low_power);

// Instantiating a FuzzyRule objects

FuzzyRule *fuzzyRule01 = new FuzzyRule(1, iffewpeople, thenlowpower);

// Including the FuzzyRule into Fuzzy

fuzzy->addFuzzyRule(fuzzyRule01);

// Building FuzzyRule "IF people = average_people THEN power= average_power"

// Instantiating a FuzzyRuleAntecedent objects

FuzzyRuleAntecedent *ifaveragepeople = new FuzzyRuleAntecedent();

// Creating a FuzzyRuleAntecedent with just a single FuzzySet

ifaveragepeople->joinSingle(average_people);

// Instantiating a FuzzyRuleConsequent objects

FuzzyRuleConsequent *thenaveragepower = new FuzzyRuleConsequent();

// Including a FuzzySet to this FuzzyRuleConsequent

thenaveragepower->addOutput(average_power);

// Instantiating a FuzzyRule objects

FuzzyRule *fuzzyRule02 = new FuzzyRule(2, ifaveragepeople, thenaveragepower);

// Including the FuzzyRule into Fuzzy

fuzzy->addFuzzyRule(fuzzyRule02);

```
  // Building FuzzyRule "IF people=many THEN power = high_power"
  // Instantiating a FuzzyRuleAntecedent objects
  FuzzyRuleAntecedent *ifpeoplemany= new FuzzyRuleAntecedent();
  // Creating a FuzzyRuleAntecedent with just a single FuzzySet
  ifpeoplemany ->joinSingle(many_people);
  // Instantiating a FuzzyRuleConsequent objects
  FuzzyRuleConsequent *thenpowerhigh= new FuzzyRuleConsequent();
  // Including a FuzzySet to this FuzzyRuleConsequent
  thenpowerhigh->addOutput(high_power);
  // Instantiating a FuzzyRule objects
  FuzzyRule *fuzzyRule03 = new FuzzyRule(3, ifpeoplemany, thenpowerhigh);
  // Including the FuzzyRule into Fuzzy
  fuzzy->addFuzzyRule(fuzzyRule03);
}

void loop()
{
  if(count>=1){digitalWrite(28,HIGH);}
else{digitalWrite(28,LOW);}
  a=digitalRead(entrance);
  b=digitalRead(exiting);

        if(a==1){
           count++;
           //Serial.print(count);
         }
         else if(b==1){
          if(count>0){
           count--;}
           //Serial.print(count);
         }
         else{
           count;
           //Serial.print(count);
         }
         if(count>2){
```

```
digitalWrite(fan, HIGH);
}
else{
digitalWrite(fan,LOW);
}
// put your main code here, to run repeatedly:
humidity = dht.readHumidity();
temperature = dht.readTemperature();
fah = dht.readTemperature(true);
if(isnan(humidity) || isnan(temperature) || isnan(fah))
{
Serial.println("Failed to read from DHT sensor!");
return;
}
heatindexC = dht.computeHeatIndex(fah, humidity); //Reading the heat index in Fahrenheit
heatindex = dht.convertFtoC(heatindexC); //Converting the heat index in Celsius
adcValue = analogRead(currentPin);
adcVoltage = (adcValue / 1024.0) * 5000;
currentValue = abs((adcVoltage - offsetVoltage) / sensitivity);
// Serial.print("Current = " );
// Serial.println(currentValue);

value = analogRead(voltageSensor);
vOUT = (value * 5.0) / 1024.0;
voltage = vOUT / (R2/(R1+R2));
//Serial.print("Voltage = " );
//Serial.println(voltage);

Power_Consumed= currentValue*voltage;
//Serial.print("Power_Consumed = " );
//Serial.print(Power_Consumed);
//Serial.println(" Watts" );
if (client.connect(serv, 80)) {
Serial.println("connected");
// Make a HTTP request:
```

```
Serial.print("GET /testcode/db_connect.php?count=");
client.print("GET /testcode/db_connect.php?count="); //YOUR URL
Serial.println(count);
client.print(count);
client.print("&humidity=");
Serial.println("&humidity=");
client.print(humidity);
Serial.println(humidity);
client.print("&temperature=");
Serial.println("&temperature=");
client.print(temperature);
Serial.println(temperature);
client.print("&heatindex=");
Serial.println("&heatindex=");
client.print(heatindex);
Serial.println(heatindex);
 client.print("&currentValue=");
Serial.println("&current in Amperes=");
 client.print(currentValue);
 Serial.println(currentValue);

 client.print("&voltage=");
 Serial.println("&voltage in Volts=");
 client.print(voltage);
 Serial.println(voltage);

 client.print("&Power_Consumed=");
 Serial.println("&Power_Consumed in Watts=");
 client.print(Power_Consumed);
 Serial.println(Power_Consumed);

 //cliente.stop(); //Closing the connection
client.print(" "); //SPACE BEFORE HTTP/1.1
client.print("HTTP/1.1");
client.println();
client.println("Host: 192.168.10.2");
client.println("Connection: close");
client.println();
  } else {
```

```
    // if you didn't get a connection to the server:
    Serial.println("connection failed");
  }
  // Getting a random value
  //int input = random(0, 80);
  Serial.print("\t\t\t People: ");
  Serial.println(count);
  // Set the random value as an input
  fuzzy->setInput(1, count);
  // Running the Fuzzification
  fuzzy->fuzzify();
  // Running the Defuzzification
  float output = fuzzy->defuzzify(1);
  // Printing something
  Serial.println("Result: ");
  Serial.print("\t\t\t Power optimized: ");
  Serial.println(output);
    Serial.println("......................................");
      delay(5000);
       }
```