UNIVERSITY of RWANDA

Research and Postgraduate Studies (RPGS) Unit

ACEIoT

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THESIS TITLE

"IoT-based Intelligent Energy Efficiency Management System for Smart Industries"

Case study

Smart industries

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African Centre of Excellence in the Internet of Things

College of Sciences and Technology

School of Engineering

Masters of Sciences in the Internet of Things

YEAR 2021

Thesis Title

"IoT-based Intelligent Energy Efficiency Management System for Smart Industries"

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By

Clement Regis Tuyishime

215028351

A dissertation submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCES IN THE INTERNET OF THINGS

In the College of Sciences and Technology

Supervisor: Dr. Frederic Nzanywayingoma

Co-Supervisor: Dr.Omar Gatera

June 2021

Student Declaration

I declare that this Dissertation contains my own work except where specifically acknowledged.

Clement Regis Tuyishime (215028351)

Signed:

Date: June 2021

BONIFIDE CERTIFICATE

This is to certify that the project entitled" IoT-based Intelligent Energy Efficiency Management System for Smart Industries**", Case study of "**Smart industries**" Is a record of original work done by** Clement Regis Tuyishime **with reg number** 215028351 **in partial fulfilment of the requirement for the award of Masters of Sciences in the Internet of Things in College of Science and Technology, University of Rwanda, Academic year 2018-2020.**

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ACKNOWLEDGEMENTS

Firstly, I thank GOD for helping me to achieve this level of studies. Deeply, I wish to thank my supervisors Dr. Frederic Nzanywayingoma and Dr. Omar Gatera, for their splendid full support and valuable advice during my Masters studies, It would have been impossible to complete well this Masters journey, if I work without their help. I thank my Mother for their selfless care, advices and warm encouragement. I also thank my sister Regine Marie Manishimwe and Pacifique Abimana for their encouragement during my studies journey. In addition, I thank the Ag. Director of Centre & director of PhD studies at the African Centre of Excellence, Dr Damien Hanyurwimfura and Head of Masters studies, Dr Didacienne Mukanyiligira for their valuable support to help me during my journey of studies. Finally, I thank also my colleagues and friends in the Centre of Excellence for the happy time they have shared with me.

Abstract

The internet of things (IoT) has been useful in different sectors and attracted more attention in researches. IoT technologies are mainly used to enable the physical objects to collect and exchange data by using wireless network protocols. Moreover, IoT technologies have been applied in different applications including energy control and monitoring. However, energy efficiency has been the main challenge in industries, when comparing the energy consumption, production and cost. Therefore, this research project will develop IoT-based intelligent Energy Efficiency Management system (IoT-IEEMS) to control and monitor selected parameters in smart industries. IoT is used to control and monitoring various parameters by using sensors and controlling units. This project will help the industries to control some parameters and the operator will be notified through email, to check regularly the values captures by the sensors and being informed if there is a problem according to the range of values that allowed to be used in smart industries. IoT-IEEMS focused on parameters such as a temperature, humidity, illuminance, noise emission, energy consumption and frequency in the industry for the various industrial equipment.

Keywords: IEEMS, Energy Efficiency Management System, Internet of Things, Sensors, Smart Industry, Wireless Sensor Networks

Acronyms List

3D: Three dimension

1G: First generation

3G: Third generation

2G: Second generation

4G: Fourth generation

5G: Fifth generation

ARM: Advanced Risk Machine

APIs: Application Programming interface

AI: Artificial Intelligence

COA: Centroid of Area

CO2: Carbon Dioxide

DRS: Department of Retirement System

EMS: Energy Management System

FCM: Fuzzy Control Model

FLC: Fuzzy Logic Controller

FCS: Fuzzy control Surface

FIS: Fuzzy Inference System

GPRS: General Packet Radio Services

GUI: Graphical User Interface

HVAC: Heating, Ventilation, and air Conditioning

ITU: International Telecommunication Union

IoT: Internet of Things

IoT-IEEMS: IoT based Intelligent Energy Efficiency Management System

ICT: Information Communication Technology

IEC: International Electro technical Commission

LoRa: Long range

LED: Light Emitting Diode

MQTT: Message Queuing Telemetry Transport

OSI: International Organization for Standardization

QoS: Quality of Services

RFID: Radio Frequency Identification

REs: Renewable Energy Sources

RSB: Rwanda Standard Board

SMS: Short Message Services

TCP/IP: Transmission Control Protocol/Internet Protocol

WIFI: Wireless Fidelity

WSN: Wireless Sensor Networks

Symbols List

C: Celsius

DB: Decibel

Hz: Hertz

Lux: Lumen per square meter

Kw: Kilowatt

P: Power

W: Watt

% : Percentage

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CHAPTER 1

1.1 Introduction

In the recent years, range of IoT applications have been developed and integrated in smart industries[42]. The development of this, started from RFID (Radio frequency Identification) technology, which allows the microchips to send the identification information to a certain reader across wireless communication technology. RFID readers, allow people to identify, monitoring and track certain objects attached with RFID tags in direct way [1].

Wireless sensor networks (WSNs) is essentially used on the interconnected smart sensors that monitor and control the environmental conditions. Its applications are including the industrial monitoring, traffic monitoring and environmental monitoring. These two technologies are mainly used for the progress of the Internet of Things (IoT) [1]. The application of the internet, system becomes secured, live data monitoring can be applied, and it is possible to use IoT system in the industrial processing and manufacturing of products[41]. For the previous generation of industries, Industry was monitored manually, but now the industry has the intellectual way to processing products without any human intervention [2].

An intelligent energy efficiency system can compromise the control units and the sensor networks on gathering high amount of data and analysed through using visualization dashboard by comparing the described data with the accurate data that considered in industries to enhance energy in smart industries. On the other, side the installation of the different sensors in smart industry required, is expensive on equipment cabling and sometimes is very hard to implement the industrial energy management system. Although this IoT-IEEMS can help to reduce the installation labour as well as the cost for the energy management system in smart industries [6].

Another technology used in smart industries is wireless sensor network. WSNs are used to tackle the issue of energy in industries and has many applications, where WSN are formed by huge interconnections of sensors to detect the physical things such as humidity, temperature, noise frequency, illuminance and energy consumptions[4] [5].

WSN are designed to be used for more application in order to satisfy the required standard on differentiating one application to another. Great effort has been put to get better of energy saving and energy management system. The potential applications are applied in smart industries, where

WSNs and energy management system have an effect in that domain, thus, we need more strategies and standardisation policies to enhance energy in industrial sector as one of the main challenge in smart industry [5].

The industry parameters like temperature, humidity, energy consumption and heating of different equipments are managed by reading the data from the sensors employed and located on the typical equipment in the industry. Using IoT-IEEMS is environmentally flexible and are cost saving for the smart industries.
In this research project, IoT-based intelligent energy efficiency management system (IoT-IEEMS) will be developed with the purpose to enhance energy efficiency in smart industries. A typical setup of such industries will be determined and simulated to observe certain important parameters that affect the energy efficiency in industries such as energy consumption, temperature, humidity, noise emission, frequency, and illumination. A smart system will be developed to analyse the data and to help an operator to act accordingly on performing the required action. This will help the industries to utilize the energy efficiently, to reduce the cost of consumption and thus to increase the benefits as well as to enhance the local economy [6].

The proposed IoT –IEEMS for smart industries is consisting of Node MCU-ESP8266 as a microcontroller of the input values from the different sensors, Wi-Fi shield, modules such as temperature sensor and humidity sensor.

The parameters values will vary depends on the conditions of the equipment usage i.e. lamp light or motor. This system will give the results on the plots, a graph based on the parameters of the sensed values of data and uploading in cloud server through MQTT protocol for the visualization of data to the Node-RED platform as a user graphic interface and make a notification to the industrial operators through using e-mail. The way this system is achieving the energy efficiency based on the equipments (i.e. motors, lamps, ventilators,etc…) and other typical equipment across the environment. This gives the operator to act accordingly to manage the energy consumption of the appliances at the industries in actual time [7].

1.2 Background and Motivation

In the global context, the energy demand is characterized by increasing 2.3% in 2018 compared to 2017, which is the high rate increased since 2010[8]. For the result of CO2 emission due to energy sector which is a record of 2018, with comparing the pre –industrial global warming is close to 1.5ºC, the increase of temperature level and most likely before the 21^{st} century [9]. The global warming is exceeding the 2ºC, which have a high impact on human life and on the planet in general. Different researches describe that a non-fossil energy system is not possible when there is no way to enhance energy and managing the energy resources (RESs) [10], not only on the country [11], level but even also to the region [12], and globally [13].

Based on the report of the United Nation on the Sustainable Development Goals (UN-SDGs) [14], to improve the energy utilization is one of the main point that drives a sustainable development, which will offer the economic sustainability for the long term by reducing the energy generation in the energy sector. For enhancing the energy efficiency in the smart industries, the high management standard is required through an effective way of analysis and real-time data in the energy supply [10].

Nowadays, Rwanda is implementing the vision of 2050 with a focus on SDGs goals with aim of economic development through industrial production as one of the key players. IoT technologies are planned to be used in the smart industries, with considering ICT technologies [15].

The IoT is currently an industrial driving technology mainly used to conserve energy and making things to be smart. In this project, the developed system will automatically show the values to the operator, monitor the industrial applications, and help to generate intelligent decisions through notification to the operator[37]. As IoT has given us a favorable well build system of smart industrial applications and systems by using wireless communication devices and sensors. This system uses IoT and wireless sensor networking in smart industries to monitor and control the industry using dissimilar sensors with an IoT-IEEMS enable the operators to make decisions; this will help the country to achieve sustainable developments based on energy efficiency in industries [2].

1.3 Main contributions

Why is energy efficiency important?

The main motivation of this research project is to build an IoT-based intelligent energy efficiency management system (IoT-IEEMS) for the smart industries that using the sensor to capture the data and send it using an internet WIFI shield module (ESP-8266). This system is able to help an operator to take direct decision in accordance to the notifications received.

Currently, in most of the industries in Rwanda, physical technicians manage the part of monitoring industrial, which leads to the inefficiency in production. As Rwanda is moving to the 4th industrial revolution, we have to apply smart devices in order to manage well the industrial processes. Therefore, this system is going to solve a problem of energy in industrial sector. This will be characterized in the following different ways but not limited to:

- Low energy consumption and high-energy efficiency in industries.
- Enhancement of mass production in industries.
- Effective cost of production.
- Improvement of health and safety of staff in industries.
- Protection of the environment.
- Facilitating industrial maintenance and operations with real time notification.
- Implementation of the fourth industrial revolution technologies in industries.
- Reduction of waste and increase of profitability in industries.

1.4 Problem Statement

Rwanda‘s energy balance shows that about 57% of its overall primary energy consumption is based on biomass (99% of all households use biomass for cooking), 11% from petroleum products (transport, electricity generation and industrial use) and 4% from hydro sources for electricity. In April 2011 about 14% of the total population had access to electricity from the grid and the government has started a roll-out programme to rapidly increase this to 16% (350 000 connections) by 2012 and 60% by 2020 [16]. Therefore, there is a need to reduce energy consumption in industries to improve the stability and whole economy of country[3][10].

The energy efficiency has been an issue in power consumption, which would be improved through reduction of power consumption and using energy efficient equipment's, this will support the industries to increase the profitability in industries and thus the profit to the whole economy[17][18].

1.5. Research Project Objectives

1.5.1 Main Objective:

- To design an intelligent Energy Efficiency Management System based on IoT Technologies for smart industries.

1.5.2. General Objectives:

- To design a system that makes intelligent decisions and able to deliver real time data databased on the control of parameters including temperature, humidity, illuminance, power consumption, noise emission and frequency.
- To implement the proposed system model through prototype and fuzzy logic by using random numbers.

1.6 Research Context

This complemented research system will help industries to manage the equipment used in industry that consuming electricity and other energy. Energy will be enhanced because this system will be intelligent by sending real time data to the industry operator in order to help them to make real time decisions and to monitor daily live data through an IoT platform. Moreover, the automatic control of appliances at the industry condition will be made by a human intervention because this system is based only on showing the data captured by the sensors through using IoT technology system.

1.7. Scope of the study

The research is limited to the following key points:

- An IoT-IEEMS that monitors and analyses the sensing parameters temperature and humidity.

- A system way that analyses the data, sends real time data to dashboard, and notify directly an industrial operator through an email.

- The visualization of results by using Node-RED through using an IoT communication protocol of MQTT.

- Control parameters: Temperature, humidity, noise emission, illumination, energy consumption and, frequency through using fuzzy control system and Fuzzy inference system.

Note: The project is expected to continue working in future on the following:

- Expanding the work to other sensing parameters in industries.
- Working on automatic actuators of machines or equipment or any other appliance in industries.
- Implement a real scenario in industry or testbed application of the proposed system model.
- Performing Fuzzy control system using accurate data values from different sensors and different parameters.

1.8. Study significance

- The current study, will contribute to the enhancement of energy and creating fine use of the existing energy consuming equipment’s in smart industries.
- This system is promoting the implementation of new energy efficiency technologies and facilitating energy management improvements by using the IoT.

1.9. Study Organisation

This research project is containing six chapters arranged in the following way:

Chapter 1

This chapter is focusing on IoT-IEEMS and focus on smart industries. This chapter also consists the background and motivation of project, problem statement, study objectives, hypothesis, study scope, significance of study, organisation of study and the conclusion.

Chapter 2 discusses about the literature review characterized by others research work review based on energy management system, it also include the images, figure and proposed solution and standards for enhancing energy management in industries.

Chapter 3 is composed by the proposed IoT-IEEMS with use case diagram and system flow chart for describing the project steps to be implemented.

Chapter 4 is composed by system architecture of the IoT system function, the system analysis design include hardware prototype, results and fuzzy logic system for describing the model and scenario of simulation of IoT-IEEMS.

Chapter 5 is composed by the implementation of results, discussions and analysis from prototype design, and fuzzy logic model proposed by using random values on the system.

Chapter 6 is the conclusion and recommendation for the improvement in the future works.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter introduces the research done on IoT-IEEMS and their findings; it also highlights the main contributions of this project in addition to the ones in literature.

2.2. Related Research

The energy efficiency is called simply and interpreted as the reduction of the energy used on certain services or for the level of an activity, and more suitably as the art of ”Doing more with less”. The renewable energy (REs) and energy efficiency are the identical standard for sustainable energy policy. There are different forms of energies utilised in industries such as electrical energy which is more suitable safe to be used in the industry[19].

The evolution of industries and internet have showed that the various benefits of the IoT in industry 4.0 which use many ways to connect things anywhere with using internet. IoT is aiming to automate actions of different domains such as industrials system, health care system, surveillance systems, telecommunication system, electrical system, transportation and many others systems [20].

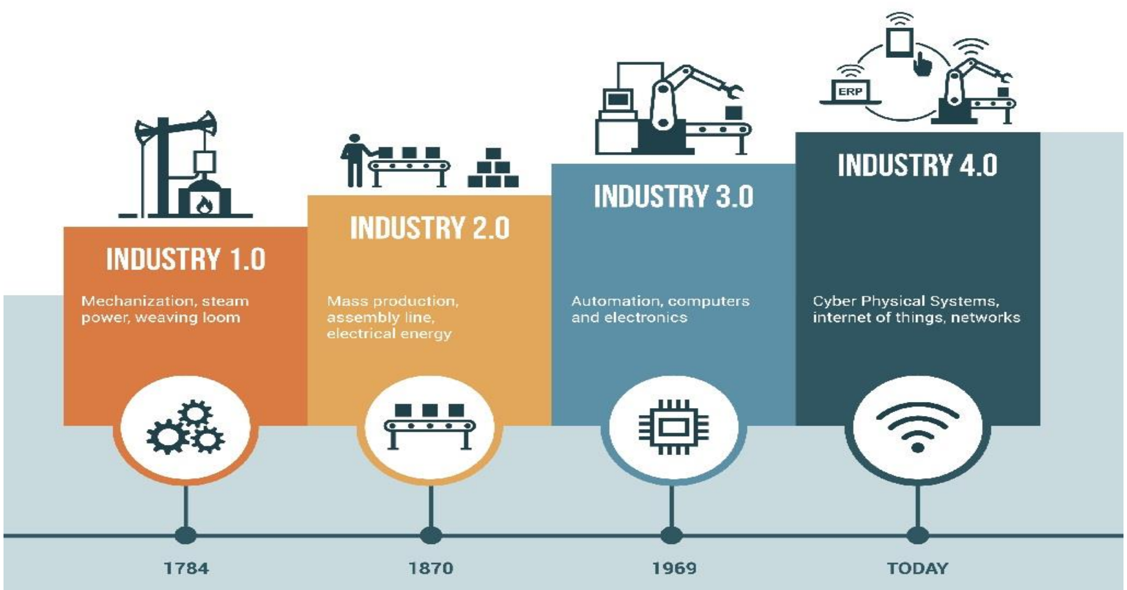

Figure 1: Industry 1.0 to industry 4.0 [14]

Industrial revolutions have divided into four parts of revolutions:

- In the first version, have characterized by the new resources of energy and shown by the running machines, the invention of steam power plants and the extractions of coal which is the significant development stage of this phases.
- In the second version of revolution, is known as an electricity generation and mass production generation leads to period of rapid development of industries and is distinguished by the exhaustive iron and steel production. Many industries in this period, their assembly lines where fixed and new brand of business are established.
- The third generations of industries revolutions characterized by the computer and is the phase of technologies based on communication such as: Mobile phones system, telephony system and automation in supply chain.
- The fourth generation introduced by the broad variety of advanced technologies in communication system such as 5G network, the intelligent robots, and Artificial intelligence (AI) big data and IoT are anticipated to warrant the industries 4.0. Hence, IoT is able to improve different processes by collecting and processing a vast amount of data in order to be more quantifiable and measurable [10].

IoT is described as network of physical objects and software combined with embedded devices, sensors and electronics to the network connection, and that will enables objects to gathering and interchange data. A system is developed, which is automatically monitor the industries operation and application to generate alerts and alarms and take smart decisions with conceptualization of Internet of things [2].

In one of the research reported, Vignesh and his team developed an IoT based smart energy management system based on temperature, which is automated, and humidity monitoring by using raspberry PI as a control system[6]. Where the system receives the values sensed and sent to internet connection. This research focused on smart home monitoring and control[21] by using user friendly GUI that has been developed to be accessed anywhere by using internet connection. System measure the temperature and current voltage of socket, and each room in house will be monitored with regard to the threshold transgression before fire or circuit breaker happen[22] [6].

In addition, in this research, they deal with controlling light system in the school room for the purpose of energy efficiency through using command on the application on android phone by using Bluetooth, which help to manage the energy level of appliances[38][23]. The demand of electricity in this research has been predicted based on the mechanism of energy demand[24].

Summary on the Indicator of energy efficiency in general with the considerations of examples:

Indicator	When Used	Examples
Energy efficiency	Individual energy-transforming technology where both input and output are forms of energy.	Electric motor (% efficiency) Lamp (lumens per watt).
Specific energy consumption	Appliances and energy-using equipment with a relatively standard output or energy service.	Washing machine (kWh per load) Building (kWh per m^2 floor area).
	More complex processes where output(s) may be expressed in common physical units.	Tea processor (MJ per kg of tea) Tin mine (GJ per t of cassiterite) Bakery (MJ per kg of product).
Energy intensity	Very aggregated entities where outputs are too diverse to be summed in physical units.	Food & beverages sub-sector Manufacturing sector Whole economy (MJ per RWF of value-added).

Table 1: Defining energy efficiency [25].

1. **Energy efficiency of Electric Motors**

Energy efficiency requirements efficiency, the nominal energy of a motor included in the scope of this regulation must not be less than the value specified of 50 Hz and 60 Hz for the specified rated output power and number of poles, at full load and under rated operating conditions. For motors with a rated output power other than the values specified of 50 Hz, but within the range of **0.75 kW-375 kW,** the efficiency value determined in accordance with the interpolation method specified in clause 5.4.5 of IEC 60034-30-1 shall apply [26].

The energy efficiency for the motor, when tested at rated voltage and rated frequency in accordance with IEC 60034-2-1, shall not be less than the nominal efficiency declared by the manufacturer in technical documentation as well as on the rating plate, after allowing for the tolerance on the total losses according to IEC 60034-1 [26].

2. Energy efficiency on lamp (LED)

Nearly 20% of total electricity production is consumed by electric lighting. By 2030, energy demand for artificial light is projected to be 80% higher than today. The introduction of more energy efficient lighting solutions is seen as a priority in many countries. Here as elsewhere, the choice of technology makes a big difference in terms of energy efficiency. Incandescent bulbs waste about 95% of electricity mostly in the form of heat [27].

3. Noise emission

RS 236, a standard on acoustic, noise pollution and tolerance limit developed by Rwanda Standard Board (RSB) provides acceptable noise levels in different areas as given in table 3.For industrial area, industries should control their equipment in order to comply with the acceptable level. The proposed system given in this research helps to achieve to the targeted level.

S/N	Types(Industry/Building)	Maximum acceptable noise level(dB/Max)
1	Offices	50-60
2	Dwellings (Houses& flats)	45-55
3	School (Class rooms)	45-50
4	Hospitals	40-50
5	Churches and Mosques	40-50
6	Residential Area	**55** during day time and **45** during night time
7	Industrial Area	**75** during day time and **70** during night time

Table 2 : Table of Maximum acceptable noise level in different Domain [28].

Energy management system are used in many organizations, which involve the creation of new measures, policies and plan for energy efficiency. That why ISO 50001 is used as a standard for energy management system for enabling organization to set the required policies for achieving energy efficiency and improve the energy management [29].

Taking an example of agro-processing industry, the figure 3 shows a typical IoT architecture for agro-processing industry and environmental applications

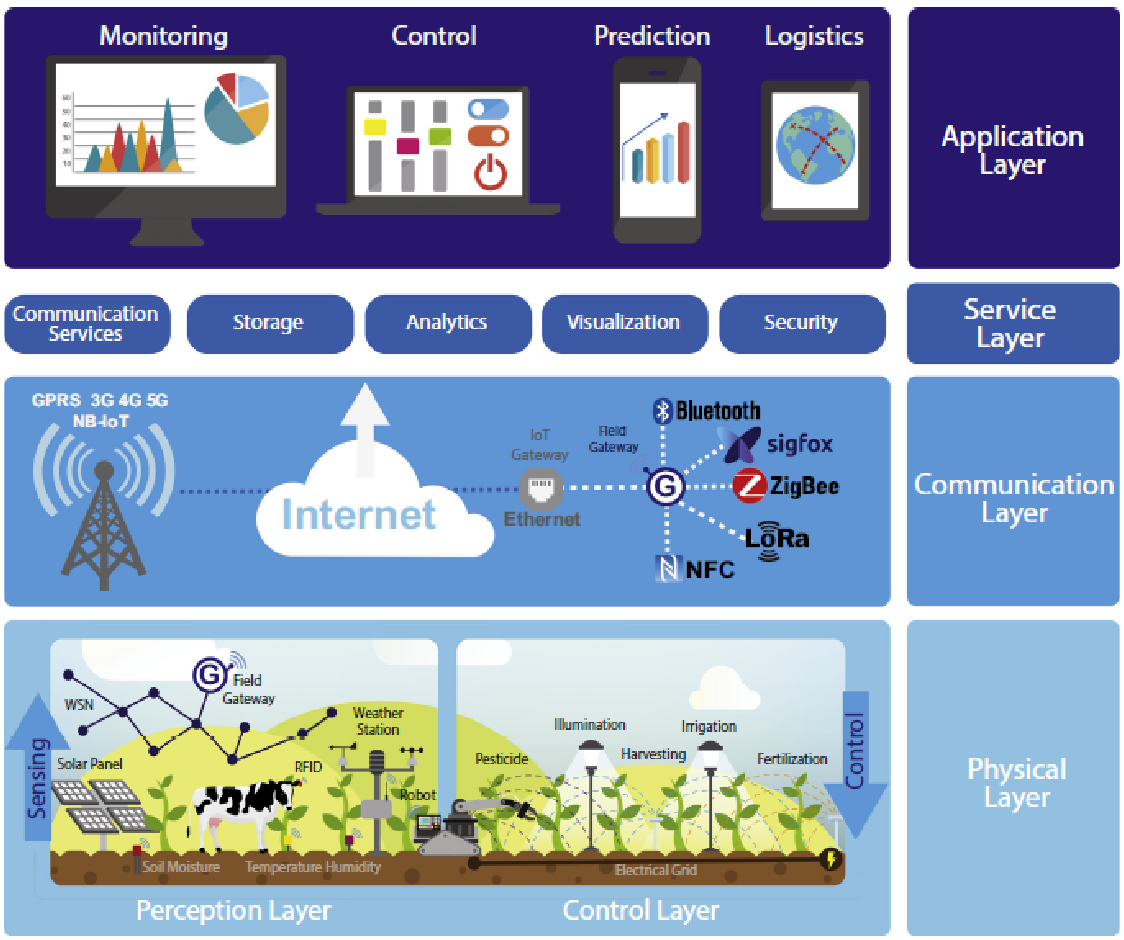

Figure 2: IoT Architecture for smart industry and environmental Applications [22].

The Fig.3; show the main layers of the OSI model such as Physical layers, Communication layer, Service layer and Application layer and these are described as follow:

Physical layer: In this layer, the main objectives is to make valuable data that are sensed in the environment using WSN, the data sensed can be sent to the communication layer through the gateway installed in the environment. The power consumptions (Low power battery and solar panels) are considered because of its lower consumptions of power. The control layer can act as a link for data on receiving information that comes from the communication layer.

Communication Layer: This layer is in charge of transporting the information from the perception layer to the internet by collecting data the data to the IoT gateway based on network connection like 4G,NB-IoT and 5G.This layer is including the field gateway that act to bond between IoT gateways and the transceivers using NFC, LoRA, Sigfox, Bluetooth and Zigbee.

Service layer: This layer controls the data slug from communication layer in addition to their analytics, security, storage and visualization.

Application layer: This layer preoccupies all services in the foregoing layer of the architecture and allow the operators/Users to play with control and monitoring.

2.3. Conclusion

This part provides different researches on energy efficiency with a focus on IoT-IEEMS and it describes different methods and various applications. This chapter includes also the evolution of industrial revolution in general, overview of energy efficiency, IEC Guidance for energy efficiency, required efficiency for typical equipment in industry and the IoT architecture for agro processing industry based on environmental applications.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

This chapter describes the research methodologies, use case diagram and system flow chart that have been applied to develop this project.

3.2. Methodology

- Review of existing intelligent energy efficiency management systems based on IoT Technologies and related algorithms in literature.
- Design a new intelligent energy efficiency management system based on IoT Technology for agro-processing industries.
- Development of algorithm for data analysis and notification for the industry operations.
- Evaluate the performance of new developed system and compare it with other existing findings in literature.

3.3. Use case diagram

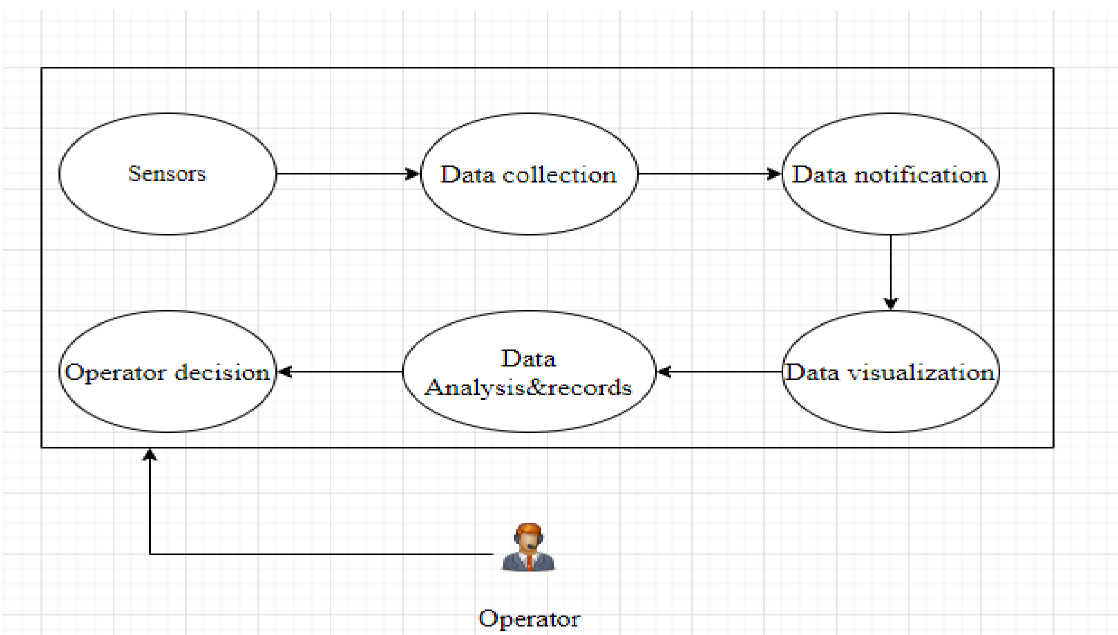

Figure 3: Use case diagram of the IoT-IEEMS.

Use case diagram shows the representation of IoT-IEEMS and the operator interaction using different cases such as: Sensors, data collection, data notification, operator decision, data analysis& records and the visualization of data.

1. Sensor: IoT-IEEMS are employed in the smart industry to captures some parameters like Temperature and Humidity for the specific purpose of collecting data.
2. Data collection: Describes the way the sensors in IoT-IEEMS will capture information from the physical things.
3. Data Notification: The data will be published and subscribed to MQTT. The designed dashboard of IoT-IEEMS and will receive a notification on the change happen when data are collected with the sensors.
4. Data visualization: The description of data will be shown by using a Node-RED dashboard through using MQTT paradigm and will help an operator to act accordingly based on values described on the dashboard.
5. Data analysis and Records: On the dashboard, the operators is able make analysis and view records on useful information of data by inspecting, transforming and take decision accordingly to enhance energy efficiency in the industries.
6. Operator decisions: Operator decision will depend on the visualization of data, an operator will act by making conclusions and a required action on different equipment's at the agro processing industry.

3.4. System Flow Chart

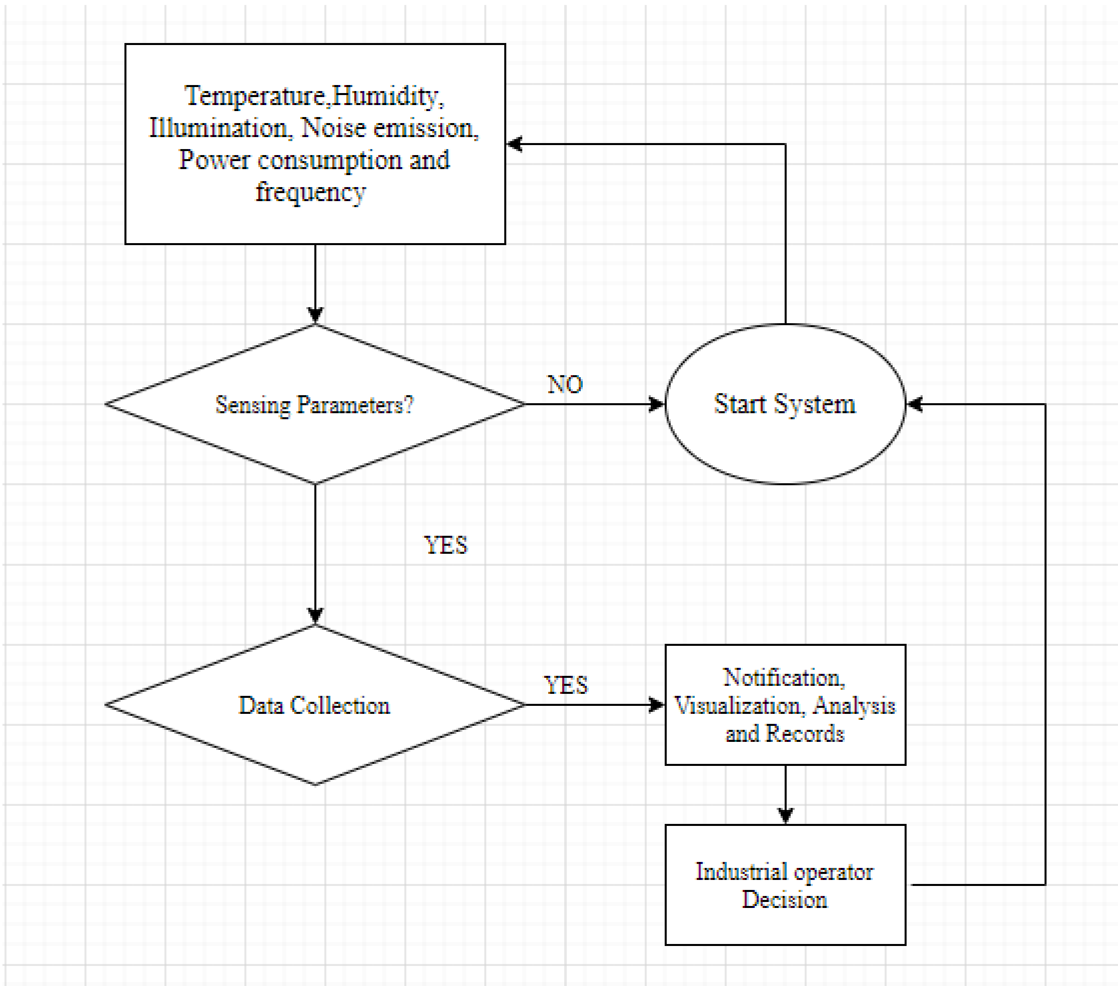

Figure 4: IoT-IEEMS flow chart for smart Industries

CHAPTER 4: ANALYSIS AND SYSTEM DESIGN

4.1. Introduction

Analysis and system design part are composed by the system architecture of proposed IoT-IEEMS, prototype equipment that include: Sensors, Wi-Fi Microcontroller (ESP 8266). While fuzzy logic method is using fuzzy control model to generate and predict the values of power consumption for considering each parameters mentioned as described on the next chapter.

4.2. System Architecture

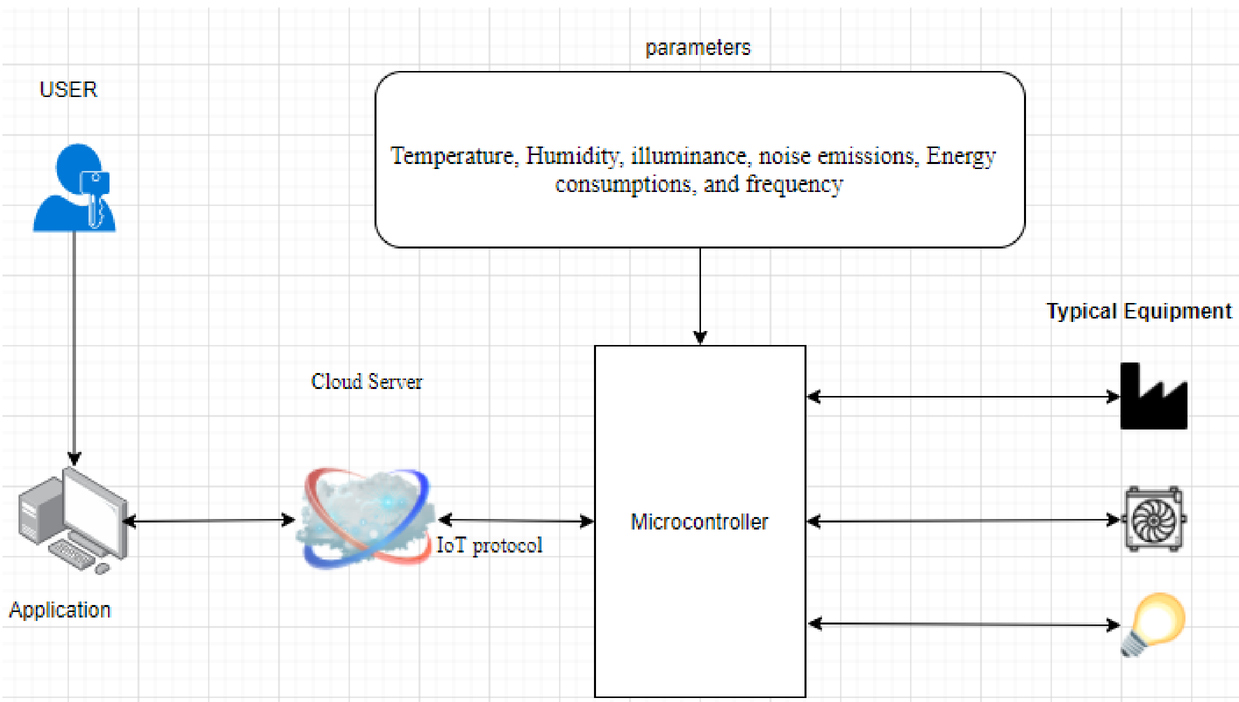

Figure 5: IoT-based system architecture model of IoT-IEEMS.

The above system architecture model in Fig.6 can be explained as follows:

Typical equipment in smart industry include but not limited to lamps, ventilators, crushing machines, drying machines, cooling machines, packaging machines among others. All these machines and other appliances consume the energy; dissipate the temperature, humidity and noise. Power frequency is the conventional value used in the electricity supply; this value should be stable for the good operation of appliances or equipment. Illumination is another important parameter in closed environment; this should be in acceptable range for the good working environment, health and safety of people. All these parameters should be observed and well regulated or controlled for the overall efficiency of the industry.

In this project, these parameters will generated within a specific period and analysed using a new developed algorithm; the results will be displayed together with the status of equipment or environment in general. The algorithm will generate values according to the threshold values obtained through the survey in industries for typical equipment and standards values available in national or international standards. The following standards will be consulted but not limited to:

- RS ISO 50001: Energy management system[29].
- RS ISO 14001: Environment management system-Requirement with guidance for use.
- RS 237: Acoustics – Noise Pollution – Tolerance limits[28].

The visualization of data make a decision to an operator to act accordingly may be “normal environment temperature, high temperature in production room or on crushing machine, normal noise emission or high noise emission in a certain room/place, normal energy consumption or high energy consumption on a particular machine/equipment, normal frequency or unstable frequency”. All these parameters mentioned above, will be generated periodically on dashboard and will help the operators to adjust the machines, replace the equipment or to perform any other maintenance activity.

The system architecture model is composed of:

1. Set up of typical equipment in agro-processing industry.

2. Microcontroller: an IoT microprocessor (node MCU-ESP 8266) programmable to perform input/output tasks using Communication protocol for data exchange.

3. Sensors: different sensors that capture the required parameters in the industry (temperature, humidity, noise emission, illuminance, energy consumption, and frequency) at any given

time. All parameters chosen to show the effect they will produce based on taking the values captured by the sensors at agro-processing industry and comparing them with an accepted value and set the required notification.

4. Cloud server: a virtual server host the data of the industry through using Microcontroller and Communication protocols for data communication.

5. Application: A web-based application (Node-RED) used to visualize and to analyse data captured with sensors. Data will be analysed, compared with the standard thresholds values, and determine the energy efficiency status of each equipment in industry. A description about the data status will be sent to the operators at industry through visualisation platform or email to intervene where necessary.

6. User: Operator or administrator in charge of controlling and/or monitoring energy efficiency in the industry when is receiving a notification.

Here below, different Sensors, protocols, dashboard and others equipment is used on IoT based intelligent energy efficiency management system (IoT-IEEMS) for Agro-processing industries:

4.3. SENSORS

Sensors are defined as smart devices that are able to transmit and collecting the environmental information in real time. Sensors are playing the major role in the development of IoT, in one of the applications like environmental monitoring, agriculture industry and health care system [30].

For the part of energy sector, the sensor are driving the saving of cost and energy at the same time. Sensors enable the smart energy management system and facilitate the optimization of the energy in real time. The use of sensors in the IoT improve decision making, real time notifications, decision-making and data analytics. Due to the large amount of sensors used in energy sector, here below are some of the applied sensors to enhance energy in agro-processing industries.

1. Temperature and Humidity (DHT11) Sensor:

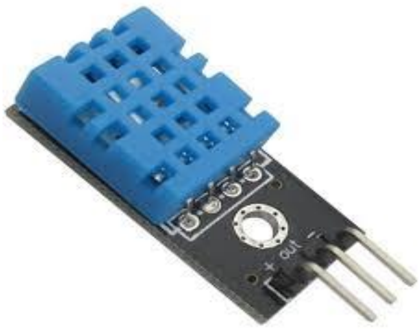

Figure 6 : DHT11 sensor [24].

Temperature are mainly used to detect the effect of heating and cooling system of a system, temperature is very important parameters in industries based on the power generation of machines in industries, where it transform electrical energy into mechanical energy and to that mechanical energy producing heat. In that case, temperature sensor act in way of evaluating and maximize the performance of system when temperature change to the normal condition. For example for the in industries area, the cooling system of machine is recognized by the temperature sensors; thus make the energy to be saved and managed well [31].

While the humidity sensor are mainly used to determine the amount of air's humidity and moisture. In the agro processing industry sector for example on the wind energy production by using machine, humidity sensor can be used to monitor the moisture. This will help the industry operators to make change and take action based on the results of moisture percentage. That will optimize the performance of the system in order to enhance the energy in industries [31].

2. ESP8266 WI-FI module:

Figure 7: ESP8266 WI-FI module

This module is a W-fi microchip that are able to make an easy connection from sensors employed in the environment (Eg: Agro-processing industries) to connect them to a WI-FI networks with using TCP/IP connections [32].

3. Message Queuing Telemetry transport (MQTT): is known as platform of protocols that helps to publish-subscribe the real time data on network using transport layer of messages between devices such as IoT industrial devices [33].

4.NODE-RED Dashboard: Node-RED described in the form of dashboard that based on flow-development that enable to connect wires and devices through using visual programming , it is mainly used in the internet of things on observing real time data generated automatically. Node-RED has creating a web browser-based on flow editor by using java functions [34].

4.4. IoT –based intelligent energy efficiency management system (IoT-IEEMS) based on Fuzzy logic

Fuzzy logic is defined as having many values in artificial intelligence (AI) or soft techniques that based on the degree of real range between 0 and 1 both inclusive. Fuzzy can be referred to as an initial that defining the uncertain crisp values x and with the correspondence membership [M] for the range of [0,1] [35].

This research will consider fuzzy logic for minimizing errors probability and will consider the random values for each parameters (Temperature, Humidity, energy consumption, Noise emission and Illuminance) at the industry by using MATLAB. Fuzzy is more flexible, has more precision and are mainly used on the industrial equipment performance like HVAC system and typical equipment [35] [39].

A. The fuzzy Control Model

The following principle considered in the design of IoT-IEEMS by fuzzy logic:

- Model fuzzification
- Model fuzzy rules
- Model inference system
- Model defuzzification

The fuzzy control model determine the appropriate probability on energy consumption based on the parameters: Temperature, humidity, energy consumption, Noise emission and Illumination.

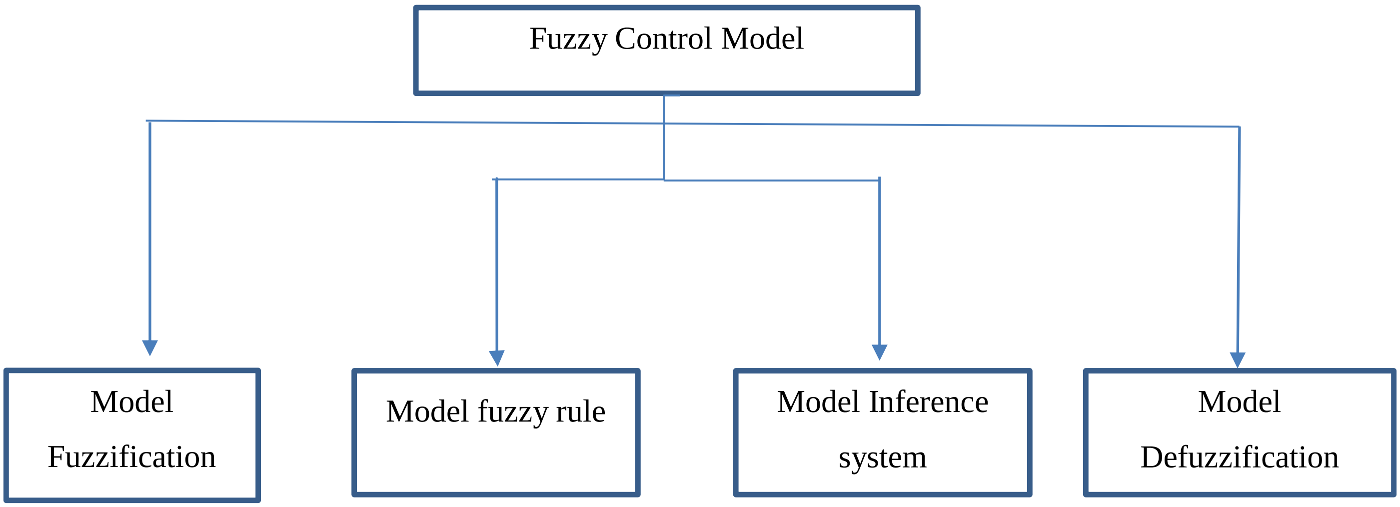

Table 3: Steps in principle of Design fuzzy approximation control model.

CHAPTER 5: RESULTS AND ANALYSIS

5.1. Introduction

The main results of this project is going to be explained in the figures below, start from hardware prototype, steps for getting real time data and fuzzy logic based on the fuzzy control model. This system of IoT-IEEMS can be used in the agro processing industries. Where the Microcontroller of Node MCU-ESP8266 used to control the whole system by receiving data from sensors that employed at the industry, and display that information directly to the Node-RED visualization platform through using Internet Protocol of MQTT.

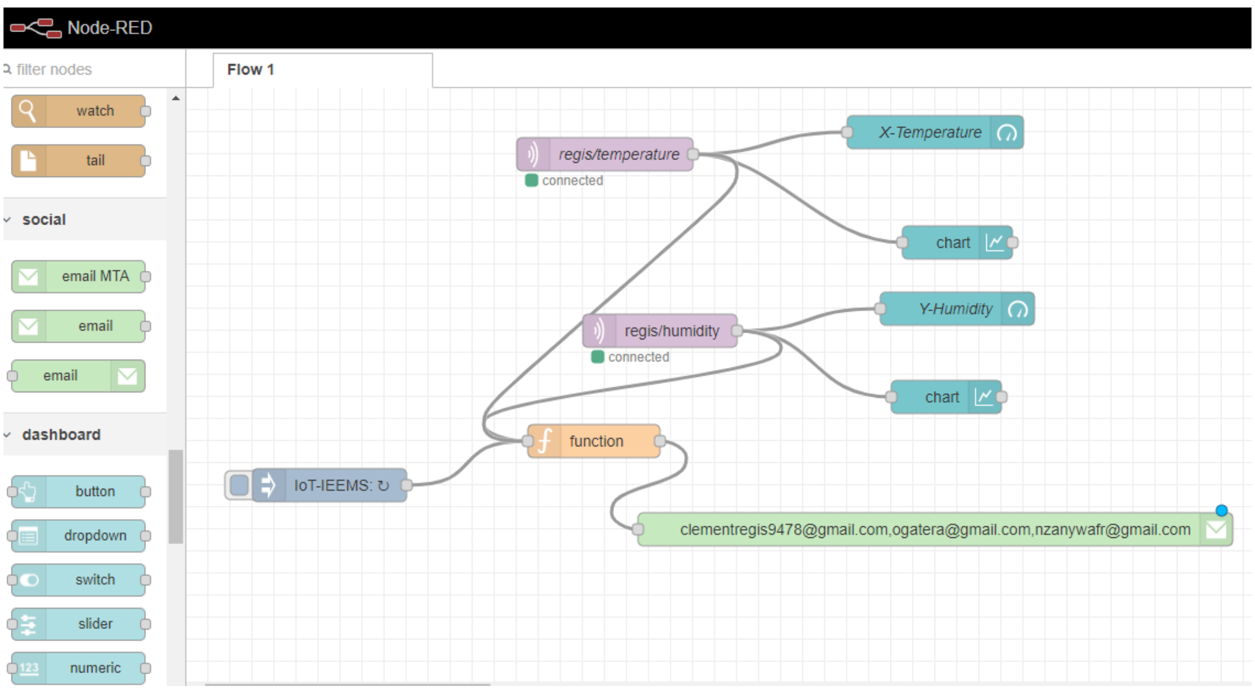

Figure 8: Node RED connection flow chart by using temperature and Humidity Sensors

Fig.10, shows the dashboard of Node-RED known as Node panel for editing , Node-RED designed as an open source for the integration of hardware devices with using APIs [34]. Node-RED described above is the interface that contain connection of regis/temperature that describe the temperature captured by temperature sensor; data will be read in the next figure by flow panel using x-temperature. In addition, regis/humidity received the data captured by humidity sensor, and will be read on the flow panel with y-humidity. As described the palette of notification is injected by the function palette, which is containing the calling function to send an email to the subscribers through using personal emails.

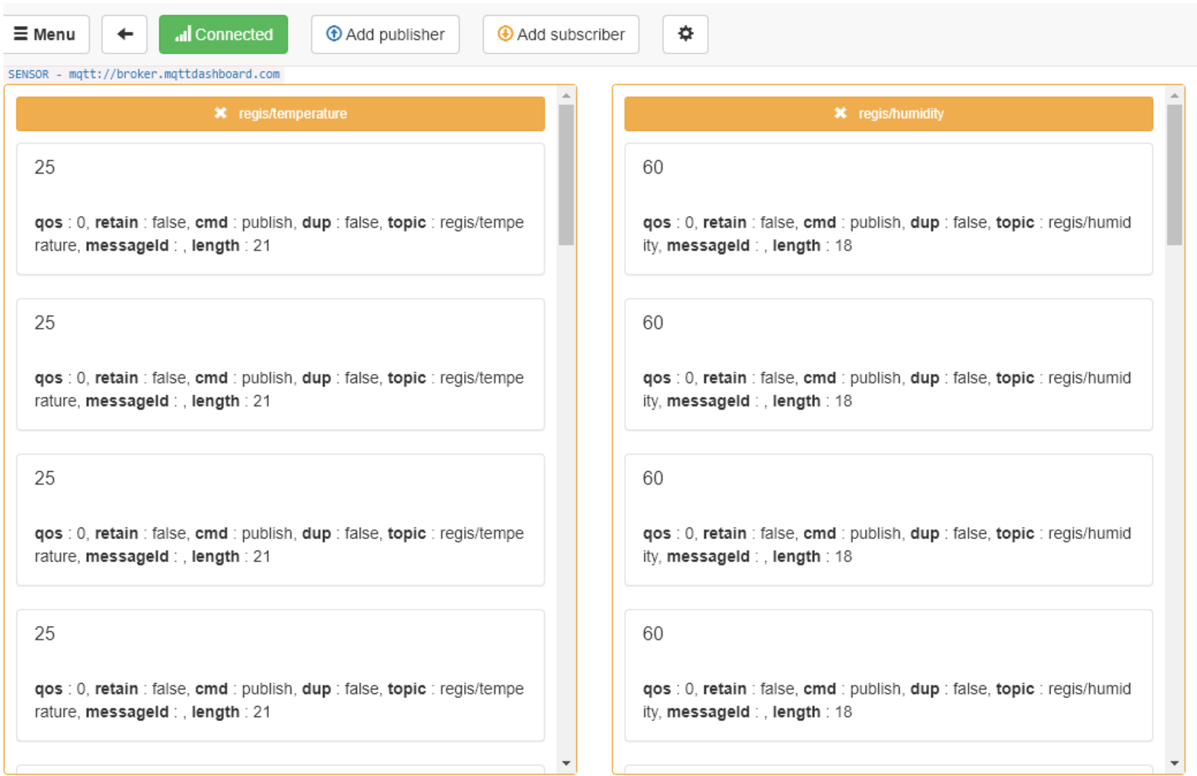

Figure 9 : MQTT dashboard for the data captured by the sensors

Fig.11, describes the way, the data captured by sensor are flowing by using this IoT real time data acquisition using MQTT protocol. For regis/temperature is recording the values of temperature from sensor and for regis/humidity is recording the values of humidity capture by sensor and all those two are used as to subscribe to the MQTT client (Node MCU-ESP 8266) and publishing data to the MQTT Client of Node-RED.

The temperature received by using regis/ temperature is 25 degree Celsius and Humidity read by regis/humidity is 60%.

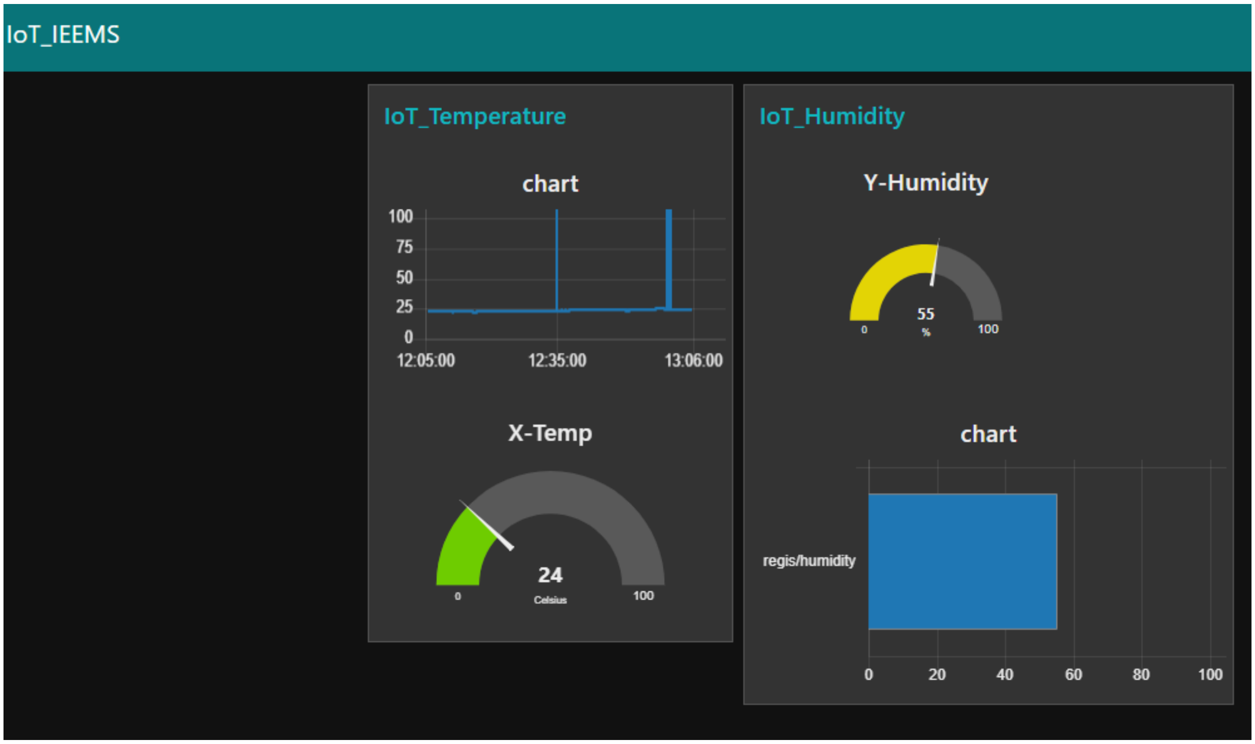

Figure 10 : Node Red data visualization in Graphs

Fig.12, shows the node flow panel to monitor directly the data on the visualization platform. The industry operators can access the platform through Graphic User Interface (GUI), they can intervene based on the real time data of humidity and temperature inside the industry and for any typical equipment, i.e. Motor or Lamp. An operator can intervene quickly for enhancing energy consumed at the industry for the problem of higher humidity and temperature or very lower of temperature and humidity.

In Fig. 12,the values of temperature is varying by using the gauge and graphs that show the way the temperature changed directly with respect to time and it's the same for the humidity is varying based on the time.

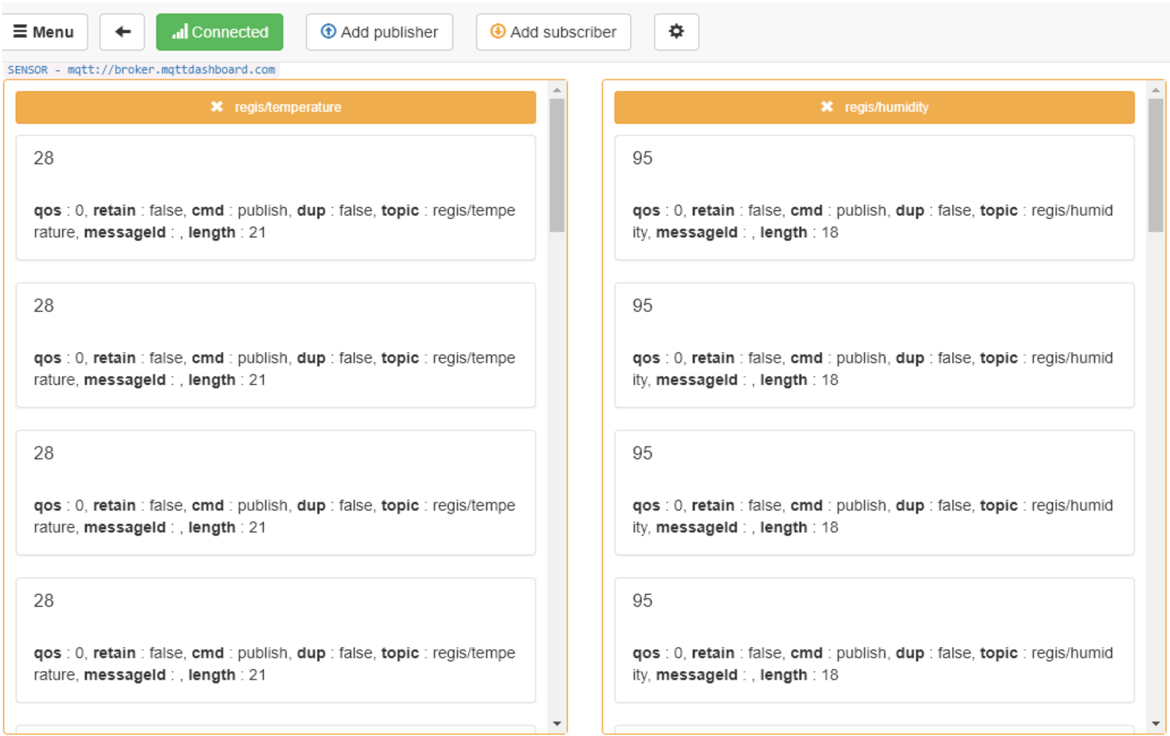

Figure 11 : Change of data on MQTT dashboard for the data captured by the sensors.

Fig.13, describes the change that happen after the rate of variation based on temperature and humidity. In agro-processing industries, when there is change made maybe based on the equipment or the environmental factor that will affect the way energy consumed to certain equipment.

Here the temperature going up to 28 degree Celsius and humidity on 95%, that show the way humidity is very higher may cause problems based on the working condition of equipment at the industry.

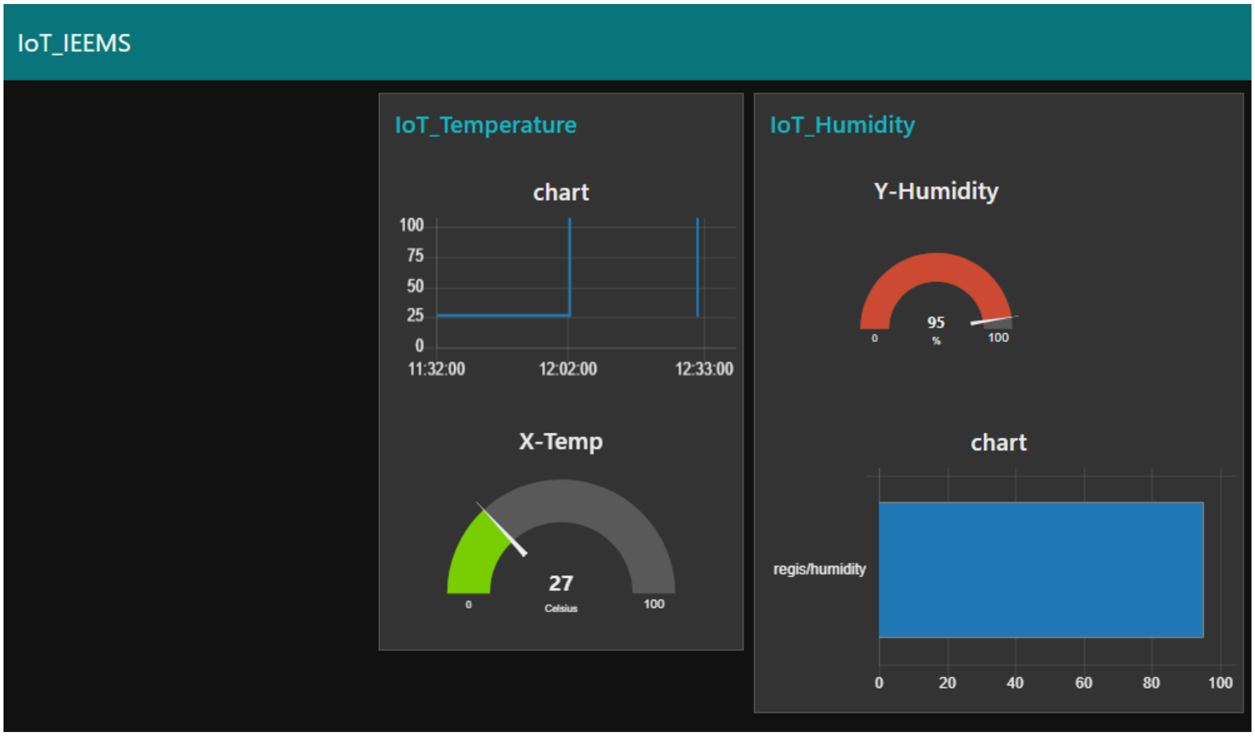

Figure 1 : Node Red data change visualization in Graphs

Fig.14, shows the variation of temperature and humidity are increasing at the same time, on the node-RED flow panel as the time changed.

The visualization of data will enhance the way data received and increased the productivity in agro-processing industry through using IoT platform to receive data and operator act accordingly in direct time.

5.3. Fuzzy logic

A. Fuzzy Control system design (FCS)

This part, shows a demonstration based on the way IoT-IEEMS use fuzzy toolbox, mamdani Fuzzy Inference System (FIS), which are integrated in MATLAB environment[40]. The random values taken for the all parameters (Temperature, Humidity, Illuminance and Noise) as inputs and Power consumption taken as an output for representing the energy consumption in IOT-IEEMS. All results are observed in in the figures below.

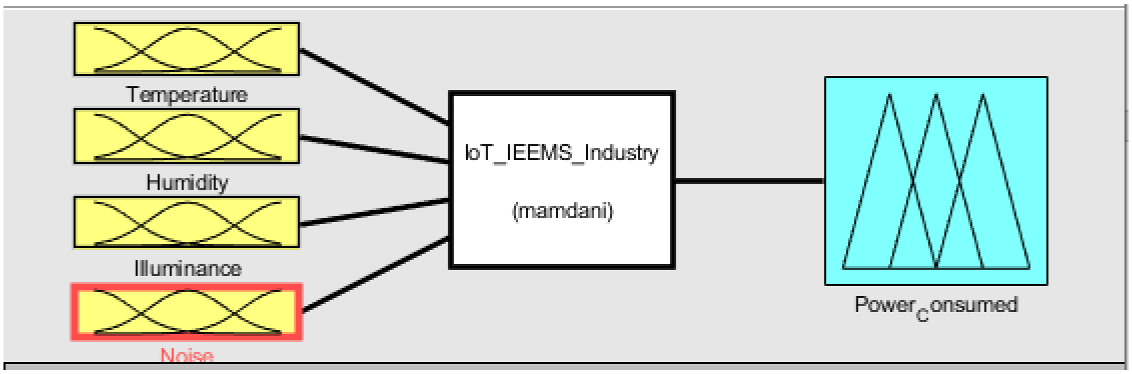

Figure 2 : Design of fuzzy control system (FCS) based on the combination of temperature, humidity, Noise emissions and Illuminance with Power consumed

Fig.15, describe the fuzzy control system design that contain all input parameters (temperature, humidity, illuminance and noise) and the Power consumed is considered as an Output with using FCS.

1. Temperature

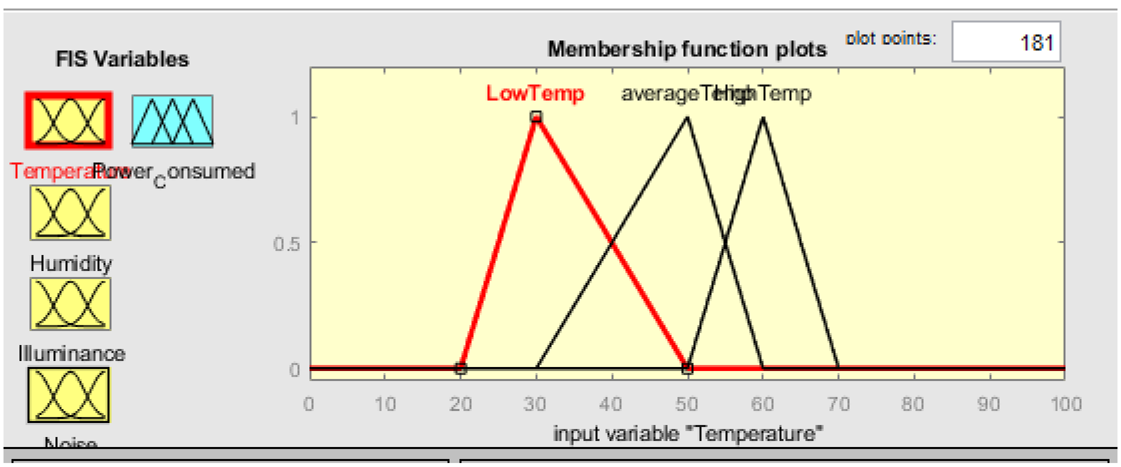

Figure 14: Design of fuzzy membership function based on the temperature

Fig.16, describes the setting of membership function based on Temperature with the chosen random values in the following way:

Low Temperature (LowTemp): [20 30 50]

Average Temperature (averageTemp): [30 50 60]

High Temperature (highTemp): [50 60 70]

2. Humidity

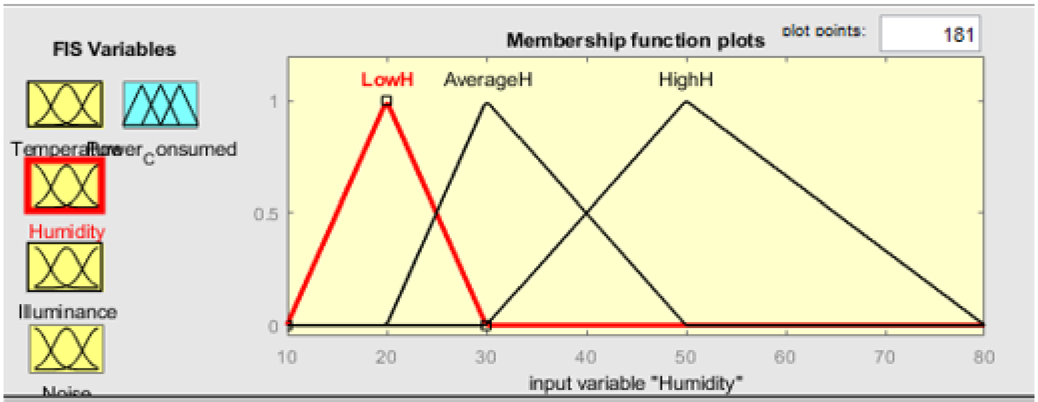

Figure 15 : Design of fuzzy membership function based on the Humidity

Fig.17, describes the setting of membership function based on Humidity with the chosen random values in the following way:

Low Humidity (LowH): [10 20 30]

Average Humidity (averageH): [20 30 50]

High Humidity (highH): [30 50 80]

3. Illuminance

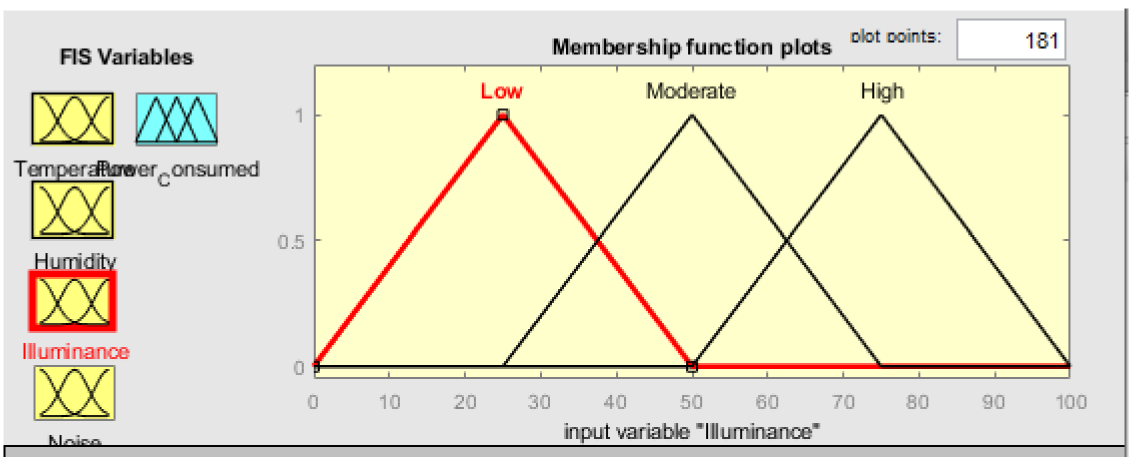

Figure 3: Design of fuzzy membership function based on the Illuminance

Fig.18, describes the setting of membership function based on illuminance as input with using the random values in the following way:

Low Illuminance (Low): [0 25 50]

Moderate Illuminance (Moderate): [25 50 75]

High Illuminance (High): [50 75 100]

4. Noise emission

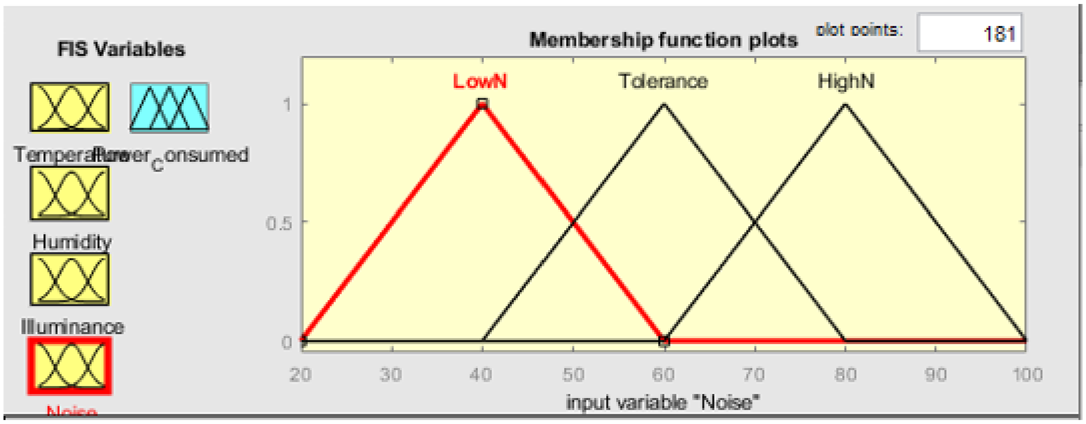

Figure 17: Design of membership function based on the Noise Emissions

Fig.19, describes the setting of membership function based on noise emission as input with using the random values in the following way:

Low noise (LowN): [20 40 60]

Tolerance Noise (Tolerance): [40 60 80]

High noise (HighN): [60 80 100]

5. Power Consumption

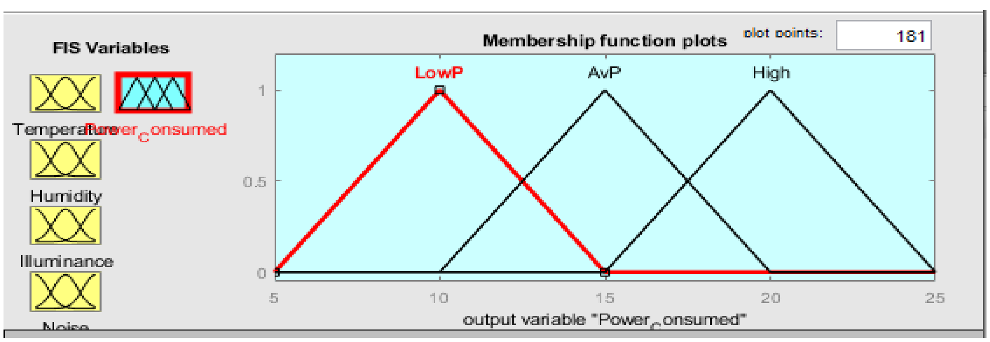

Figure 18 : Design of membership function based on the Power consumed

Fig.20, describes the setting of membership function based on power consumed as output with using the random values and have the same graphs based on the taken random values of intervals that are described in the following way :

Low power (LowP): [5 10 15]

Average power (AvP): [10 15 20]

High power (HighP): [15 20 25]

B. Description of Results analysis and Discussions on Fuzzy Logic

After doing simulation of the proposed fuzzy control, the results can be expressed in those two different graphs by showing the power consumed based on energy efficiency prediction with considering the parameters, which are taken randomly on the estimated numbers based on the requirement values for every parameter at the industry. The predicted values for power consumed is obtained by using the random inputs values for each parameter. Here below is the Initial environment parameters: temperature, humidity, illuminance, Noise emissions versus power consumption.

In the fig.14,15,16,17 and 18 show the experiment results with comparing the values taken from the sensor with in the environment, the rate of change on temperature, humidity, noise, illuminance affect the rate of change on power consumption.

The output parameter of power consumption, which is predicted by using Fuzzy logic controller, describe the energy consumed in IoT-IEEMS prototype, the results are graphically comparable and significantly the methodology used is enhancing energy efficiency with regarding to the condition prescribed in the literature review in ISO 50001 [29].

C. Fuzzy Logic Control Surface

The control surface are described by the centroid of area with using three dimension (3D) view, as Fig.20 show, the combination of parameters using temperature and humidity as input versus Power consumed as output and of Fig. 21 described by the combination of parameters include Noise and Illuminance as input versus power consumption as output.

1. Temperature and Humidity control surface

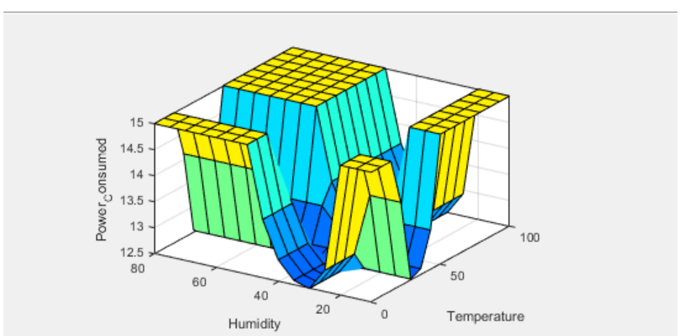

Figure 49 : Temperature, humidity versus Power consumed in IoT-IEEMS.

In this Fig.19, the values taken of temperature and humidity increase, the power consumed on the equipment increase and as the values of temperature and humidity decrease, the power consumed is decreasing.

2. Noise and Illuminance control surface

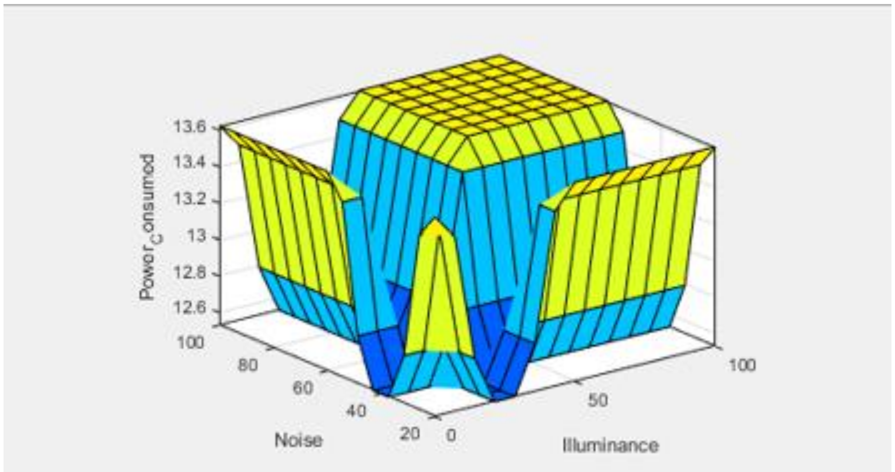

Figure 20 : Illuminance and Noise emissions versus Power consumed in IoT-IEEMS.

In this Fig.20, the values taken of illuminance and Noise emission as increasing, the power consumed on the equipment increase and as the values of illumination and Noise emission decrease, the power consumed is decreasing.

D. SURFACE VIEW

1. Temperature

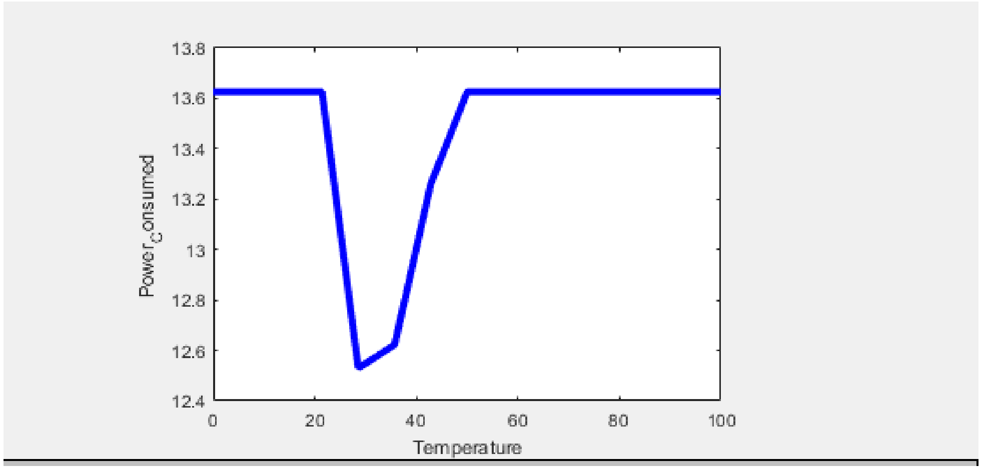

Figure 21 : Temperature versus Power consumed in IoT-IEEMS.

The Fig.21 describes the fuzzy control surface variation on the power consumed based on temperature taken randomly, where power is consumed on high level from temperature range of

]0-24] and [28-100[, but on the noise emission range of [24-28] energy consumption is average and low.

This characterizes the enhancement of energy or power consumed with regarding to the variation of temperature emitted with a certain industry equipment's used in the agro-processing industry.

2. Humidity

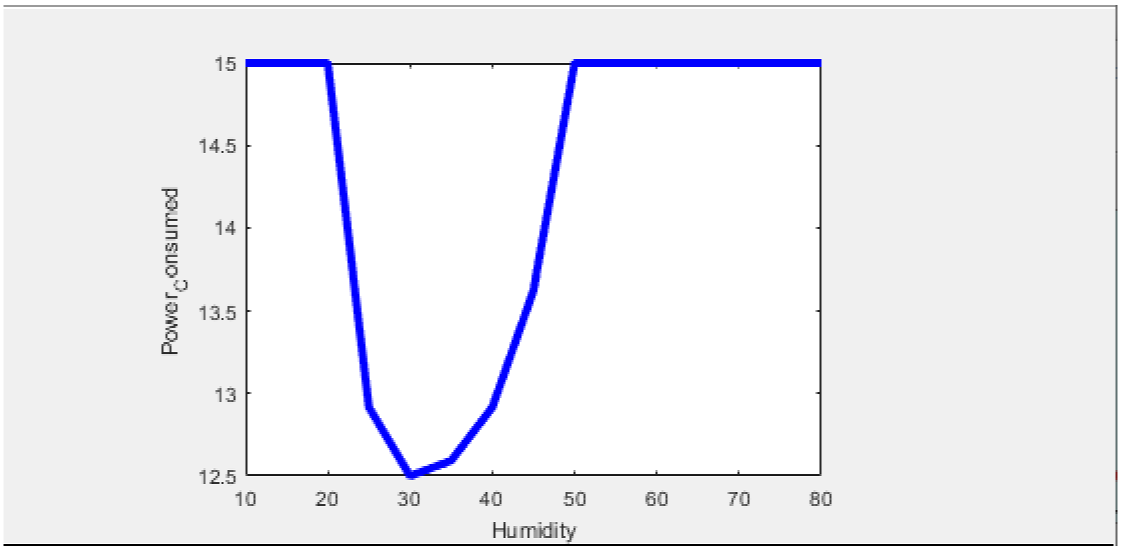

Figure 22 : Humidity versus Power consumed in IoT-IEEMS.

The Fig.22, describes the fuzzy control surface variation on the power consumed based on humidity values taken randomly, where power is consumed on high level from humidity range of]10-25] and [45-50[, but on the humidity range of [25-45] energy consumption is average and low. This characterize the enhancement of energy on power consumed with regarding to the variation of humidity emitted with a certain industry equipment's used in the agro-processing industry.

3. Illuminance

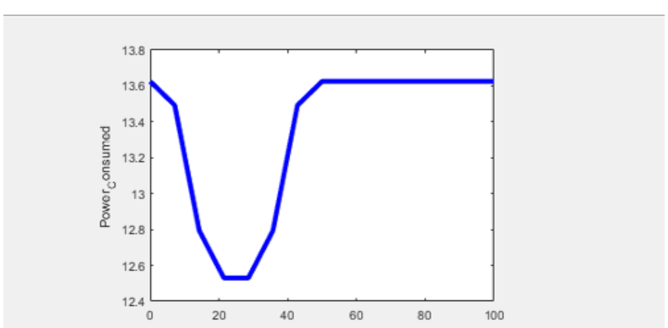

Figure 23 : Illuminance versus Power consumed in IoT-IEEMS.

The Fig.23, describes the fuzzy control surface variation on the power consumed based on illuminance emitted by equipment by using random values, where power is consumed on high level from]0-18] and [28-100[of luminance, but on the range of [18-28] of luminance, energy consumption is average and low.

This characterize the enhancement of energy on power consumed with regarding to the rate of change based on illuminance emitted with equipment's such as lamp and others equipment used in the agro-processing industry to emit the luminance.

4. Noise

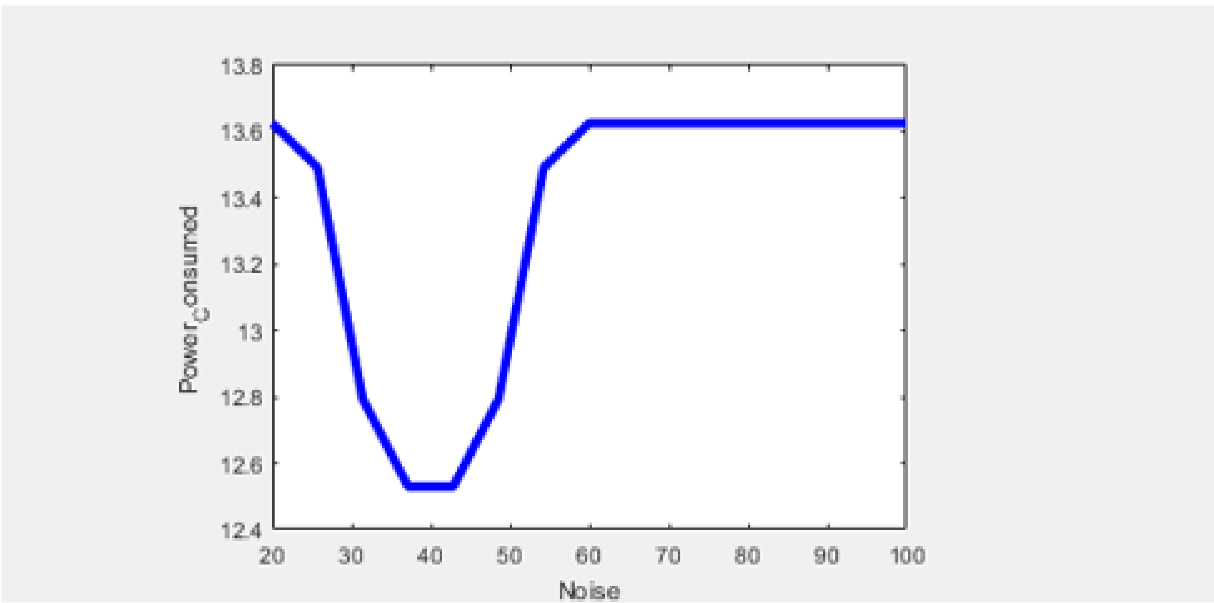

Figure 24 : Noise emission versus Power consumed in IoT-IEEMS.

The Fig.24 describes the fuzzy control surface variation on the power consumed based on noise emission taken randomly, where power is consumed on high level from noise range of]20-30] and [50-100[, but on the noise emission range of [30-50] energy consumption is average and low. This characterize the enhancement of energy or power consumed with regarding to the level of noise emitted with a certain industry equipment used in agro-processing.

E. MATLAB evaluation fuzzy Rules view for IoT-IEEMS

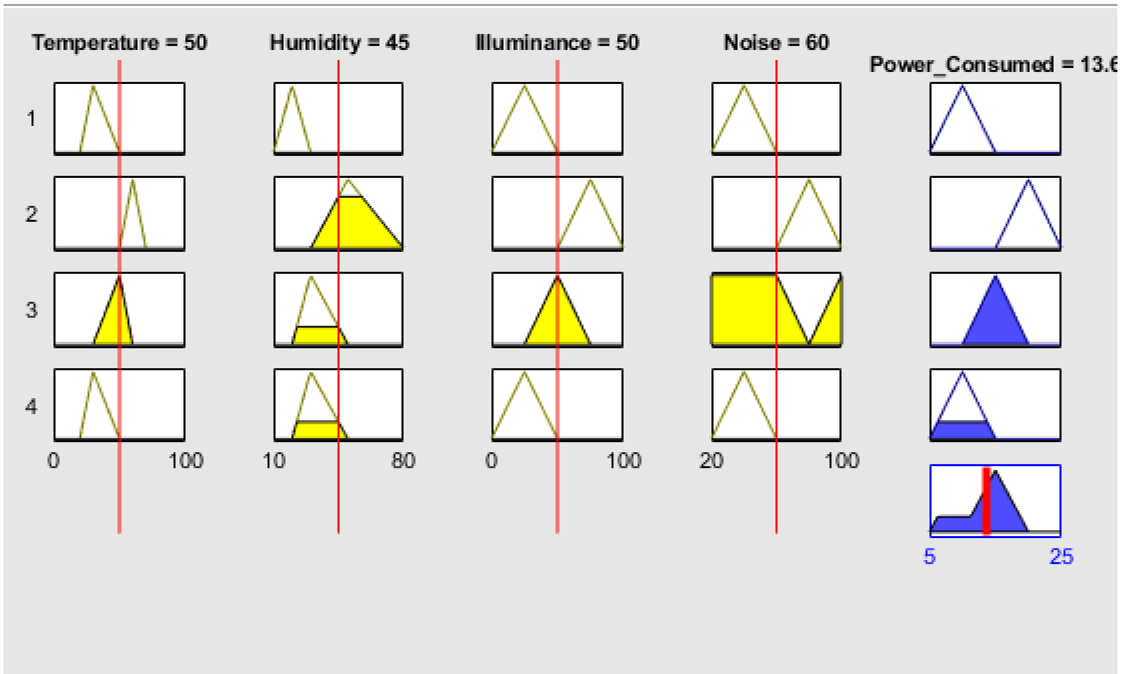

Figure 25 : Rules view of temperature, humidity, illuminance and noise versus Power consumed in IoT-IEEMS.

The output of the fuzzy system are described as a crisp number [36], then defuzzification model can be shown in Fig. 25, which is demonstrating the result effects of the different parameters we have considered in agro processing industry: Temperature=50 Celsius, Humidity=45%, Illuminance=50lux, Noise=60decibel versus with the power consumption=Watt.

The parameters considered is expressed in their units:

- Temperature(T):Degree Celsius(C)
- Humidity: Percentage (%)
- Noise emission: Decibels
- Illuminance: Luminous intensity(Lux)
- Power Consumed: Watts(W) OR Kilowatts(KW)

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The study of the proposed system that uses the IoT-IEEMS for the case of agro process industry has been conducted. The configuration of the various parameters based on temperature, humidity, noise emission, illuminance and power consumption can be considered in the implementation of the project in agro-industries, where all parameters will be monitored in real time and this project took a lot of courage, technical and theoretical initiative of the engineering practice to be deployed in industry 4.0.

The IoT-IEEMS has shown that the visualization of live data on dashboard or any other graphic user interface (GUI) and the fuzzy logic used to describe the role of enhancing energy efficiency Industry 4.0. It is most important to help the agro-processing industries operators to act accordingly in the industries based on the direct monitoring of data flow from the different sensor employed at the industry; the system implemented is limited with the prototype and random data generated in fuzzy logic.

6.2. Recommendation

Based on the findings, the current project has shown that the proposed system can be recommended to enhancing energy efficiency in industries and implementing a smart system that can achieve to the industry 4.0 objectives. In future, we propose an addition of real time notification by using GUI, alert and email. The actuator will also be considered to be used to control directly the appliances at the industry and algorithm can be improved to use the collected real time data from sensors for increasing the accuracy on the operator's decisions.

In addition, this project is expected to continue working in future on the following:

- Expending the work to other type of industries and increasing the sensing parameters.
- Working on automatic controls, real time notification and operations of machines or equipment or any other appliance in industries.
- Implement a real scenario in industry or testbed application of the proposed system model.

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APPENDIX

1. **Code for IoT-IEEMS using Arduino**

```
#include <ESP8266WiFi.h>
#include <PubSubClient.h>
#include <DHT.h>
#define DHTPIN D2
#define DHTTYPE DHT11

DHT dht(DHTPIN,DHTTYPE);

const char* ssid = "ClementRegis-IoT";
const char* password = "44884488";
//const char* mqtt_server = "192.168.0.50";
const char* mqtt_server = "broker.mqttdashboard.com";
//const char* mqtt_server = "iot.eclipse.org";
WiFiClient espClient;
PubSubClient client(espClient);
long randNumber;
void callback(char* topic, byte* payload, unsigned int length)
{
} //end callback
void reconnect() {
  // Loop until we're reconnected
  while (!client.connected())
  {
    Serial.print("Attempting MQTT connection...");
    // Create a random client ID
    String clientId = "ESP8266Client-";
    clientId += String(random(0xffff), HEX);
    if (client.connect(clientId.c_str()))
```

```
    {
      Serial.println("connected");
     //once connected to MQTT broker, subscribe command if any
      client.subscribe("Industry Operator_message");
      //client.publish("Attendance","Regis Detected");
    } else {
      Serial.print("failed, rc=");
      Serial.print(client.state());
      Serial.println(" try again in 5 seconds");
      // Wait 6 seconds before retrying
      delay(6000);
    }
  }
} //end reconnect()

void setup() {
  Serial.begin(9600);
  delay(100);
  dht.begin();
    Serial.print("Connecting to ");
    Serial.println(ssid);
    WiFi.begin(ssid, password);
    while (WiFi.status() != WL_CONNECTED)
    {
      delay(600);
      Serial.print(".");
    }
  randomSeed(micros());
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
  client.setServer(mqtt_server, 1883);
```

```
  randomSeed(analogRead(0));
}
void loop() {
  if (!client.connected()) {
  reconnect();
  }
  client.loop();
  client.setCallback(callback);
  float t=dht.readTemperature();
  float h=dht.readHumidity();
  char cshum[16];

  char cstemp[16];
  itoa(t,cstemp,10);

  itoa(h,cshum,10);
  client.publish("regis/temperature",cstemp);
  client.publish("regis/humidity",cshum);
  delay(1000);
}
```

2. System membership function for IoT-IEEMS

```
[System]
Name='IoT_IEEMS_Industry'
Type='mamdani'
Version=2.0
NumInputs=4
NumOutputs=1
NumRules=0
AndMethod='min'
OrMethod='max'
```

```
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='input1'
Range=[0 1]
NumMFs=3
MF1='mf1':'trimf',[-0.4 0 0.4]
MF2='mf2':'trimf',[0.1 0.5 0.9]
MF3='mf3':'trimf',[0.6 1 1.4]

[Input2]
Name='input2'
Range=[0 1]
NumMFs=3
MF1='mf1':'trimf',[-0.4 0 0.4]
MF2='mf2':'trimf',[0.1 0.5 0.9]
MF3='mf3':'trimf',[0.6 1 1.4]

[Input3]
Name='input3'
Range=[0 1]
NumMFs=3
MF1='mf1':'trimf',[-0.4 0 0.4]
MF2='mf2':'trimf',[0.1 0.5 0.9]
MF3='mf3':'trimf',[0.6 1 1.4]

[Input4]
Name='Noise'
Range=[0 1]
```

NumMFs=3

MF1='mf1':'trimf',[-0.4 0 0.4]

MF2='mf2':'trimf',[0.1 0.5 0.9]

MF3='mf3':'trimf',[0.6 1 1.4]

[Output1]

Name='output1'

Range=[0 1]

NumMFs=3

MF1='mf1':'trimf',[-0.4 0 0.4]

MF2='mf2':'trimf',[0.1 0.5 0.9]

MF3='mf3':'trimf',[0.6 1 1.4]