CLOUD BASED ENERGY MANAGEMENT IN BUILDINGS USING IoT FOR EFFICIENT USE OF UTILITY POWER

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OCTOBER, 2021

ABSTRACT

This research work introduces a novel human detection sensor on an IoT node so as to increase the efficiency of sensing human beings in a building, it also provide power management and control since Nigeria supply far less than what was actually demanded, based on the power baseline report submitted to the office of the vice president in 2015, which stated that only 10% of the power demanded was supplied, these couple with the fact that energy wastage is rampant in the country. This thesis presented an efficient energy management in buildings using Internet of Things (IoT) by construction of an IoT based human detection system and IoT based power management and control system. The power management and control IoT board make use of contactless current sensor which make the installation far easier, as many literature uses either the series resistance method or the current transformer method for sensing flow of current through a given load. The prototype was successfully implemented, installed and tested, the system was developed to run in the real world and several data was generated. Based on the data generated and analyzed the system was found to have 38% energy saving since the load is always automatically off when no human being is in the office that it was installed.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Nigeria is a nation yet to find a sustainable solution to the challenge of electric power supply shortage. Despite the increasing population, in 2015 it was documented in Nigeria power baseline report, which was submitted to the office of the vice president, that about 40.7% of Nigeria population are not connected to the national power grid. As for those connected, power supply has been a real predicament as about 90% of the total power demanded was not adequately supplied. As at 2015 the total installed capacity was 12,552MW and average operational capacity was 3,879MW out of which 7.4% was lost in the process of transmission and up to 27.7% was rejected at the distribution. This leaves the whole country with about 2,519MW (20% of installed capacity). In the same year Nigeria electricity demand was estimated to be 24,380MW, which means that just 10 % of the power demand was actually supplied. It is therefore not supersizing that Nigeria was ranked the second poorest electric power supply in the world, as it generated approximately 5,000 MW of power for the population of over 150 million people as compared to the second largest economy in Africa which is South Africa, that produces over 40,000 MW of energy for 62 million people. (The advisory power team report, 2015.)

In an estimation based on per capital consumption, South African generates 31 times higher than Nigeria while Ghana with a smaller population generates 2.9 times higher than Nigeria.(Https://www.power-nigeria.com/en/industry-news/poor-power-supply-in-nigeri a-what-is-the-reason.html, 2019.) This clearly indicate that Nigeria is generating far less than what the country actually required.

Despite the shortage of electric power supply, a lot of wastage and inefficient utilization is encountered at the consumer end. This wastage or inefficient utilization can be attributed to either carelessness or forgetfulness of users who often leave appliances such as security light and other electrical appliances on, even when they are not needed, especially in public buildings, and users ignorance of using energy saving devices. Moreover there are no sufficient feedback mechanism for the occupant of a building on their power consumption except for the monthly utility bills. The monthly utility bills only give indication of bulk consumption and does not indicate per appliance consumption, therefore one cannot easily detect current leakages or faults within the building, which gives rise to additional power wastage.

Currently, communication networks have knitted the globe together such that anyone can reach anywhere from anywhere, and the Internet is at the heart of these networks. Internet of Things (IoT) was listed as one of the most common applications of internet in recent time. It has been defined in many ways according to different literatures but IoT can simply be defined as a technological way of connecting anything from anywhere in any field through the internet as shown in Plate I (Achary & Jenith, 2017), (Wu *et al.*, 2017), (Mahmoud *et al.*, 2016).

Plate I: Illustration of IoT (Mahmoud *et al.*, 2016)

Connection of anything from anywhere now makes it possible for us to connect every home appliance to the Internet in other to measure, monitor and control its power consumption. The idea in this project was to use the ever growing IoT technology to effectively manage, and record data of power consumption in buildings. This will enable building occupants monitor their power consumption on the go, as well as control it remotely. Also, with a human detection sensor node in the IoT system, certain appliances can be controlled automatically whether or not, the user forget to power down the appliances when it’s not in use. An IoT device monitoring the power consumed in the building with ability to control the appliances, working in conjunction with another IoT device monitoring human presence in a given space in the building such as rooms, this will surely go a long way in solving the problem of power wastage in the country.

1.2 Statement of the Research Problem

Despite the shortage of electric power supply (The advisory power team report, 2015.), a lot of wastage and inefficient utilization is encountered at the consumer end. This wastage or inefficiency in power usage can be attributed to either carelessness or forgetfulness of users who often leave appliances such as security light and other electrical appliances switched-on when they are not needed especially in public buildings. Moreover, there is no feedback mechanism for the occupants of a building on power consumption level, except for the monthly utility bills. The monthly bills only give indication of bulk consumption and does not indicate per appliance consumption; therefore, one cannot easily detect current leakages or fault within the building, which gives rise to additional power wastage. Additionally, there is no regional or national power consumption data that could, over time, help the government and/or the power company to plan or make policy on power generation and usage. Manual collection of such building energy consumption data capturing mechanism that could be quite tedious and cost prohibitive (Akkaya *et al*., 2015).

1.3 Aim and Objectives of the Study

The aim of this project is to develop an IoT based energy management and control system to archive energy efficiency in buildings. To realize this aim, the objectives of this research is to:

1. Develop a contactless IoT based energy measurement and control system.
2. Develop an IoT based human detector sensor node.
3. Develop a web application to save the data generated by the IoT device and provide an interface for control of connected appliance by every user.
4. Test and evaluate the developed system i.e. objectives 1, 2, and 3.

1.4 Justification of the Study

To manage electricity consumption in this country based on what is generated and consumed, it is paramount to generate consumption data at varying granularity. Knowing building consumption data will be beneficial to individuals and also to the national electricity managers. However it will be very difficult and cost prohibitive to generate this data manually. Developing an IoT system to ease data collection and control remotely and/or automatically control appliances becomes very important in other to achieve efficient management of energy. Considering the fact that Nigeria is still generating far less than the load demand based on our growing population, an efficient energy management of the available energy is key.

1.5 Scope of the Study

The focus of this work is on development of an IoT system for energy monitoring and control of an air conditioning unit in a building which will also collect hourly energy consumption data for the air conditioner and store same in the cloud. The system consist of an IoT device for energy monitoring and control, an IoT based human detector sensor node to sense human presence in a room and react according to the program, a web application to interface the two IoT device in the cloud for remote control of the air conditioner and for storage of the air conditioner hourly power consumption data. The project will not focus on the implementation of the Gateway but rather make use of a Wi-Fi modem or any Hotspot for its communication to the web server, and the maximum load capability of the switch (AC Socket) shall be limited to just 30A.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

The world energy industry is facing serious challenges according to the report by world energy council (Smith, 2018), particularly in the developing world such as Nigeria where we actually supply less than 10% of the total energy demanded, despite the increasing population. A very good way of curbing energy scarcity is by reducing or possibly avoiding energy wastage by efficiently using the little that is available, and also collecting data of energy consumption so as to aid energy planning and future management. Leveraging on existing technology and infrastructure such as communication network like the internet can facilitate efficient energy management.

Internet is the interconnection of computers placed in different location in the world, Internet is currently linking billion of devices worldwide, and is used to send and receive data all over the world. Internet has vast uses and applications, in May 2019 it was recorded that were are 4.38 billion users of internet around the world which is more than 56% of the world population. *(*www.internetworldstats.com/stats.htm, 29-04-2019*.)* One of the most important and now very famous applications of the Internet is IoT (Reddy, 2017). IoT is one of the leading technologies that is being worked on to develop more consumer friendly and effective devices which help in our day to day activities in other to solve most pressing human problems. IoT has been define in many ways according to different literatures but in a simple words IoT is a technological way of connecting anything from anywhere in any field through the internet (Achary, 2017), (Wu *et al.*, 2017). Connection of anything from anywhere now makes it possible for us to connect every home appliances to the internet in other to measure, monitor and control their power consumption. Energy can be more efficiently managed when technology like IoT is employed. The spread of communication networks and the advent of IoT has made automatic and remote control of things feasible, for example IoT has been applied in areas such as health, agriculture, car packs, smart homes and building, efficient power management etc. Specifically IoT has been useful in smart home systems and efficient energy management in buildings.

2.2 Review of Smart Homes

IoT in smart cities and homes can be categorized in many ways based on the existing works. It can be based on home automation or based on home energy monitoring and management. Bhide *et al.* (2015) presented a work based on effective IoT application for monitoring environmental condition and controlling in buildings, they also provided fault detection and correction in devices connected to the system. It can be noted that every device (thing) connected to their system will be automatically connected to the internet, this make it possible for the developed system to provide a flexible and cost effective home automation system. Plate II shows the implemented design that indicated an efficient use of IoT but energy consumed by the appliances was not put into consideration.

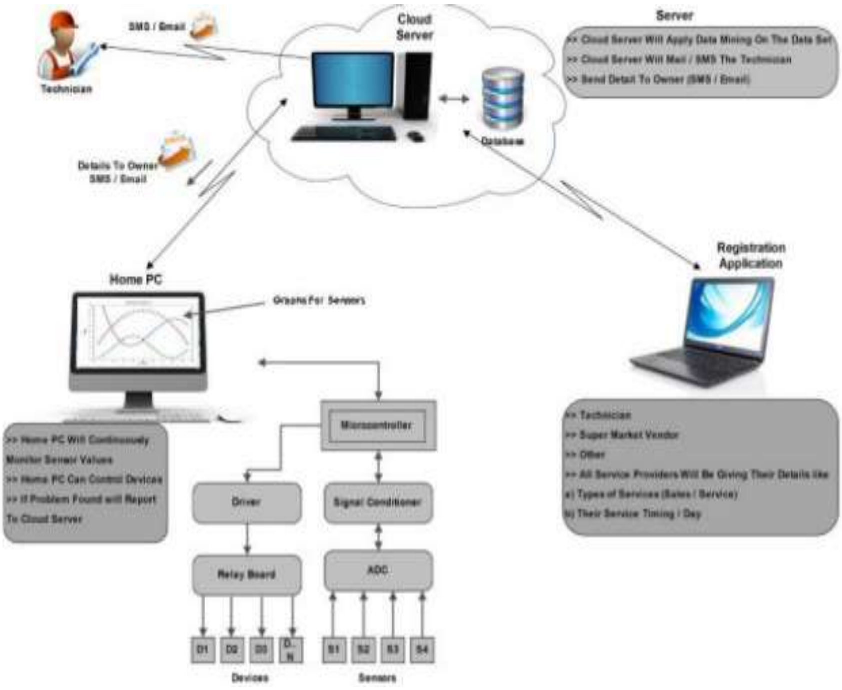


Plate II: Proposed Architecture in (Bhide *et al*., 2015)

Another work done by Akkaya *et al*. (2015) shows the implementation of the building management system (BMS), the low-level monitoring of the occupants and the communication infrastructure composed of intelligent devices such as sensors, cameras, RFID, meters and actuators. These smart devices and communication infrastructure are called the Internet of Things. BMS manages several key components of a building, such as heating, ventilation and air conditioning (HVAC), gas, lighting, security systems, and fire protection systems, and can communicate with IoT devices.

However, there are no available systems that exist in market which provide automation and also error detection in the devices. In Bhide *et al*. (2015) system, prediction method was used in finding out the expected solution, in case any problem occurs in any device connected to the system. To achieve there set aim, data mining concept was employed, and for efficient data mining Naive Bayes Classifier algorithm was used to find out the possible solution. This gives their work upper hand on other available home automation system, and a real intelligent system was achieved, which was a bit similar to the work done by Anita *et al*. (2016) which shows power consumed by the devices, controls the devices and calculates electricity bills. It however does not actually perform any form of analysis on the data collected and also do not implement any prediction model towards an efficient power management. It was pointed out in the work by Anita *et al*. (2016) that the energy crisis due to the industrial development and population growth tremendously increased the demand for energy. Their work was achieved through the use of Arduino board, sensors and a raspberry pi, connected to each and every device. They also developed a website that allows user access information about energy consumption by all devices upon login. The power consumption information is properly represented on the site that was developed, it also alert the user of power consumption if it exceeds certain levels. It was not restricted to limited devices, but if it must be used in the industries it will require using more Raspberry pi micro-controllers which will definitely increase the cost and will become more complex when the Raspberry Pi increases to anything more than 10. Pan *et al.* (2015) constructed a unique IoT experimental test bed for energy efficiency and building intelligence. It was formerly monitored and data was collected on the energy usage of the building for a year, and then systematically evaluated and analyzed it. They proposed a framework for the IoT system, which has smart location-based, grid-based automated power control, using smart phone platforms and cloud computing technology to achieve multi-scale power ratios. In addition, they constructed a proof-of-concept network for the Internet of Things and a prototype control system, and conducted actual experiments to prove the effectiveness of the proposed solution. They stated that the wide application of the proposed solution not only produced significant economic benefits in terms of energy saving and improving the intelligence of building networks, but also had a huge social impact in terms of global sustainability.

Smart city has been described by many authors as a relatively new concept (Calvillo & Villar, 2016; Dobrescu *et al.*, 2018). In a very simple way, smart cities aim to address or alleviate the problems caused by rapid urbanization and population growth through greater efficiency and optimization of resources, such as energy supply, management of waste and mobility. Many classifications of smart city intervention areas can be found in the literature. A disadvantage of these classifications is that they mainly classify energy based on smart grids, ignoring other related energy elements such as transport and facilities. Plate III shows the classification of energy intervention area in smart cities.

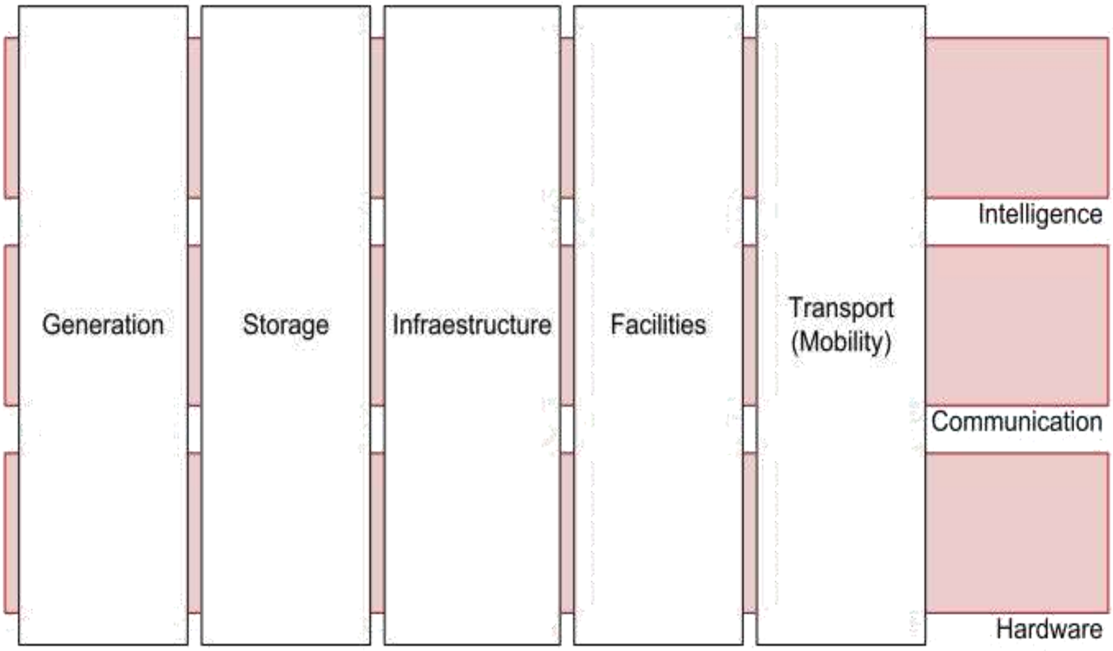


Plate III: Classification of Energy Intervention Area in Smart Cities(Calvillo & Villar, 2016)

2.3 Review of Energy Management

A framework for designing, implementing and deploying IoT applications was presented by Chauhan *et al.* (2017), where by platform application was developed, consisting of a suite of tools for simplification of IoT application development. The authors' IoT suite supports generation of code automatically and integration of modeling set of languages, accepting high level specification as input abstracting related complexity. The IoT suite integrates compiler and deployment environment module to provide automation at different aspect of application development process, Plate IV shows the graphical representation for smart home as presented by the authors.

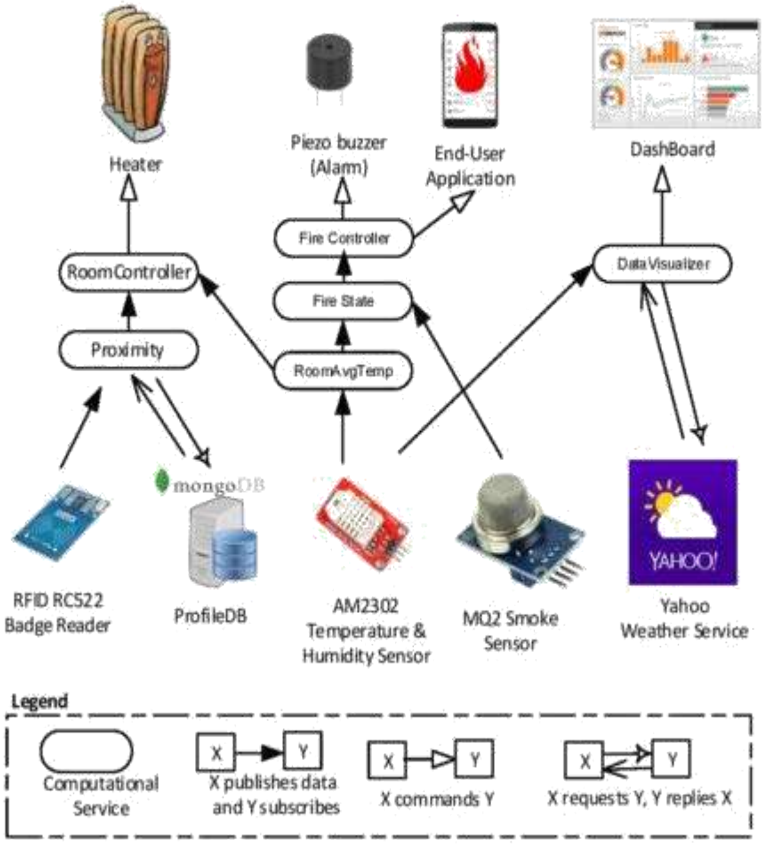


Plate IV: Data Flow for a Smart Home Application (Chauhan *et al.*, 2017)

Another work where IoT framework was presented is Lu & Cecil (2015), where a foundation for cyber physical interaction and collaborations for an advanced manufacturing domain. The authors presented a discussion of the framework for micro device assembly domain, the data/information exchange between various physical and software components is modeled using Engineering Business Modeling Language (eEML) to provide a structured foundation for the design and development of this IoT-based collaboration framework. The document introduces the main network physical components and modules, and then discusses the implementation of the framework. But efficient power consumption of the frame work in Chauhan *et al*. (2017) and Lu & Cecil (2015) does not document much of efficient power consumption for IoT application as was communicated in Mahmoud & Mohamad, (2016), where the study of efficient power consumption using wireless communication techniques and modules for Internet of things applications, and also showed the significance of using low power wireless communication techniques and modules in IoT applications. The method of the study employed in Mahmoud & Mohamad (2016) was in terms of protocols used and the particular module that achieved that protocol. Based on connectivity range, each module protocol was classified. ZigBee, 6LoWPAN and low power Wi-Fi were shown to be suitable for short range connectivity, while LoRaWAN protocol was presented to be accurate for long range connectivity and was finally concluded that the choice of the modules for each protocol determines battery life span due to different power consumption for each module or protocol used.

Power efficiency in IoT is necessary so as to sustain the module and save energy when IoT module become massively deployed as expected in the nearest future. Wae *et al.* (2016) proposed a design and characterization of inductors for self-powered IoT edge devices. The author discussed the design, manufacture and characterization of flat inductors encapsulated in nickel-zinc (magnetic materials). The authors studied the importance of different sizes in inductor performance and the relevance of model hardware. The manufacturing process shows that the inductance is increased by a very simple procedure of applying magnetic materials on both sides of the inductor, and the geometry can be flexibly customized to minimize the energy loss in the IoT architecture. After adding NiZn ferrite material to both sides of the inductor, compared with air-core inductors, the inductance of the two substrate thicknesses studied in this paper increases by about 60% to 80%.. Since increase in population indicate an increase in the number of deployed IoT module, Palattella *et al.* (2016) described and analyzed When considering technology and standardization, the potential of 5G technology for the Internet of Things is presented in detail. The paper also reviewed the current Internet of Things connection landscape and the main 5G drivers of the Internet of Things, finally explaining that the tight connection between the Internet of Things and 5G can cause large-scale business transformations in markets. Ecosystems of operators and suppliers. From cloud computing to Internet of Things technology, the rise of Mobile Cloud Computing (MCC) as a new technology refers to the infrastructure in which data storage and processing is operated outside of the Internet of things to save energy. The interaction and collaboration of things and objects that send data through wireless networks is to achieve the objectives set for them The author proposes the rapid development of cloud computing and the "Internet of things" in the field of communications wireless. Therefore, while demonstrating how cloud computing technology can enhance the functions of the "Internet of Things", this article also discusses the "Internet of Things" and cloud computing, focusing on the problems of security of these two technologies. The highlights of his research are the benefits of integrating the Internet of Things and cloud computing. Some Advanced Encryption Standard (AES) algorithms are proposed to improve security issues. This is due to the integration of IoT and cloud computing technologies with another algorithm called RSA. RSA is an Internet encryption and authentication system that uses an algorithm developed in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman (RSA). RSA algorithm enables integration and reduces energy consumption in IoT modules(Stergiou *et al.*, 2016).

2.4 Review on Development of Power Management and Monitoring IoT Board

A proposed IoT based energy aware smart home control system using a coordinator-based ZigBee networking as a means of its wireless communication was presented in (Khan *et al.*, 2016). The author used smart interference control system (SICS) to provide remedy for high packet loss by interference from coexistence of heterogeneous wireless technologies. The authors also included a smart energy control system that comprised of household appliance control system and lighting control system support by ZigBee sensors coupled with electrical appliances and light sensors in the smart home. According to the result presented this system improves energy consumption efficiency in a smart home in relation to renewable energy like sunlight. The simulation result showed that the proposed system is less affected by interference but this paper make use of a current sensor that implemented series resistance method of measuring current. Another IoT based power monitoring system and control was proposed by (Raju *et al*., 2017). The authors designed a real-time and efficient wireless networks to monitor power utilization of electrical appliances. This design uses circuit to measures current flowing into and voltage across an appliance, thus power is estimated. Raspberry pi board is placed at the load. This triggers an electromagnetic transfer that can change the condition of the appliances. An android application was used to give order to web facilitator and in turn the web send the command to the raspberry pi board. In this design, consumed power values and the control of gadgets can be obtained remotely. This author also used series resistor as a method of measuring current, which will require series connection of the wireless sensor node to the power line. This technique may not be easy to install as it will require breaking walls or cutting wires of the appliance supply line.

Another similar work was reported in Rakeshkumar & Rakesh (2017), the authors proposed an IoT based gateway for electrical energy meter through ZigBee technology. Using IoT, energy consumption and theft at the consumer end can be monitored and controlled remotely from a company office. Current and voltage sensors were placed at the energy meter. Microcontroller collects energy data from the meter which uses a current transformer (CT), and sends to the company office using ZigBee network. At the company end, the energy meter data is received by microcontroller which publishes the data on web page using GSM module. The company can disconnect consumer from power consumption if he fails to pay the bills by sending control commands to the energy meter. In case of theft, alert will be sent and displayed on the terminal screen of the company. This paper is able to reduce human involvement in monitoring energy meter and energy theft.

Study *et al*. (2017) Proposed a case study on IoT based energy meter for billing and monitoring. The authors used GSM, IoT web server, relay display device and microcontroller for the realization of the proposed design. The consumer can monitor their own energy usage in respect to billings. Based on IoT, the company can remotely terminate consumer energy supply if the consumer fails to pay his bills. This system also uses a current transformer method as its means of sensing current.

Mani *et al*. (2017) proposed a method of controlling appliances intelligently instead of just switching them ON and OFF, the IoT based smart energy management system utilizes Machine-to-machine communication, environmental sensors, Arduino microcontroller, Wi-Fi module and Android to control appliances. Fan and bulb are wirelessly controlled based on humidity and light intensity. This system also provides the consumer a real time power consumption of his appliances and help in efficient use of energy. Gobhinath *et al*. (2016) utilized wireless technology for automatic meter reading system. The device proposed uses ARM7 microcontroller to compute electricity consumption. The current sensor used in this work is also the series resistor method, which is then fed into the microcontroller. Measured consumption, billing information and payment are communicated between electricity board unit and the consumer unit using IoT. In this work, theft can be identified and consumer supply can be terminated remotely.

A low cost PZEM-004T, non-invasive CT sensors, SD3004 electric energy measurement chip and ESP8266 Wemos D1 mini microcontroller was used for retrieving data from sensor nodes. With this, a low cost IoT energy monitoring system was realized in Chooruang (2019) and Chooruang & Meekul (2018). The data from the microcontroller was sent to a server through the internet. The authors' design can measure voltage, current, active power and cumulative power consumption. This IoT based system was suggested by the author to be used as a remote electricity billing system, home automation and energy management in smart grid. Their design was based on current transformer method for monitoring current and voltage transformer for monitoring voltage, Plate V shows their schematics.

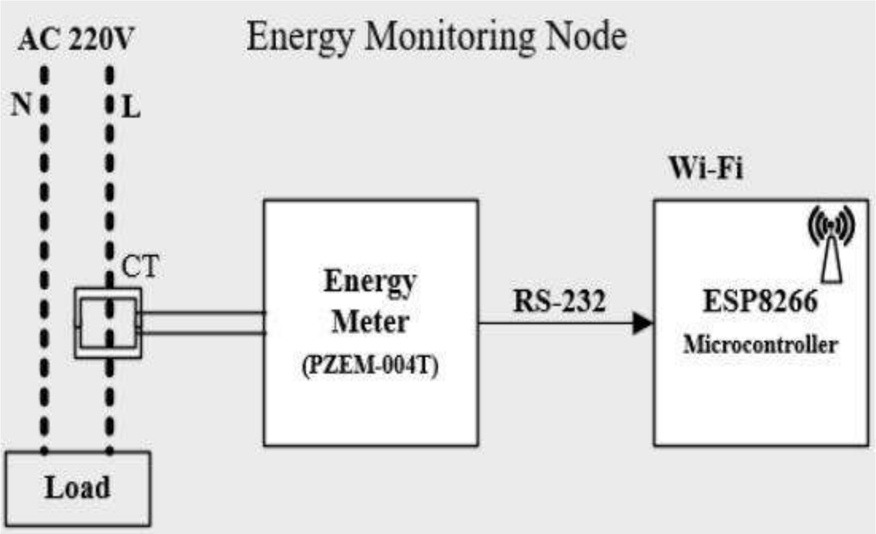


Plate V: IoT Energy Monitoring Module Using Current Transformer (Chooruang & Meekul, 2018)

Talwar & Kulkarni (2016) Proposed IoT based energy meter reading that informs the consumer the number of energy unit consumed globally. This system measures energy consumption, uses telemetric communication to generate billings automatically. WIFI ESP8266 module which is the type proposed in this project work because of it low cost and its low power consumption, was used to connect the IoT by uploading consumption information on the web server for remote access. The authors of this paper showed that the IoT based meter can automatically turn off power supply if the consumer failed to pay bills. Also, power theft detection alert will be send to electricity board unit as well as on the web server. It made use of the current transformer method of sensing current flow too. The Internet of Things is internally related to computer skills and transfers data over the network without the help of person-to-person or person-to-computer interaction. Pujari (2018) proposed an intelligent energy monitoring system based on the Internet of Things using ATMEGA328, buzzer, LCD, meter pulse and Wi-Fi module (ESP8266) that works under six AT commands. Monitoring energy is easier using IoT, in this system, data can be transferred or received from the utilities. Supply can be disconnected through the internet if bills are not paid by the energy consumer. The work by Tao *et al*. (2016) observed the relationship between IoT and product life-cycle energy management. The authors in this paper showed that application of IOT is demonstrated in product life cycle; design, production and services. In the area of design, IoT helped to optimize raw materials procurement, simulation and testing of product. While in production, IoT will facilitates real-time monitoring, workshop transporting scheduling and predict efficient working method of the manufacturing equipment. IoT in service will provide efficient transport planning, energy conservation use guide, online enquiring, auto product inspecting etc. Thus, IoT can be extensively used to enhance product life-cycle energy management. Sahani *et al.* (2017) proposed IoT based smart energy meter using energy efficient Arduino, Wi-Fi module, GSM module. The authors' design does not particularly replace the old meter but a modification of it, though still using the series resistor method to measure current flow. Their design featured SMS notification, internet web page, and automatic on and off of meter and threshold value setting. With IoT, energy meter can be monitored and controlled remotely via mobile phone and internet web page.

In a paper by Hiwale *et al*. (2018), digitization of load energy usage reading over the internet is proposed The IoT based energy monitoring design uses ESP 8266 Wi-Fi module, Arduino Nano board, current and voltage sensors to publish energy consumption over the internet. The internet uses "THINGSPEAK" analyzer to describe the energy usage. This gives more details and visual concept of power consumption. The authors design gives the consumer authority over his energy management, remotely. IoT based power consumption monitoring and control system was proposed to mitigate energy efficient impairment (Harsha *et al*., 2018). In this work, the design monitors power usage of the consumer and cut off power with respect to threshold. This system can be placed before transmission of the load in each house. This model has a meter that produce continuous pulse, which through Wi-Fi gateway, communicates with the internet. Energy supplier can now monitor and control end users power consumption from a remote area.

The system also send notification to supplier and a data sheet can be generated using LabVIEW, the implementation of this work was also done by using current transformer as the current sensing unit. Karthikeyan & Bhuvaneswari (2017) proposed a real-time IoT based monitoring system for residential energy meter. The paper utilizes the IoT technology to present energy consumption to the users. This information is available at any place or time. The system uses SoC for control and communication. The paper also showed through experiment that collected data can be used to generate energy consumption pattern. Existing meter can be upgraded without going for a complete replacement. Plate VI shows the implemented system architecture.

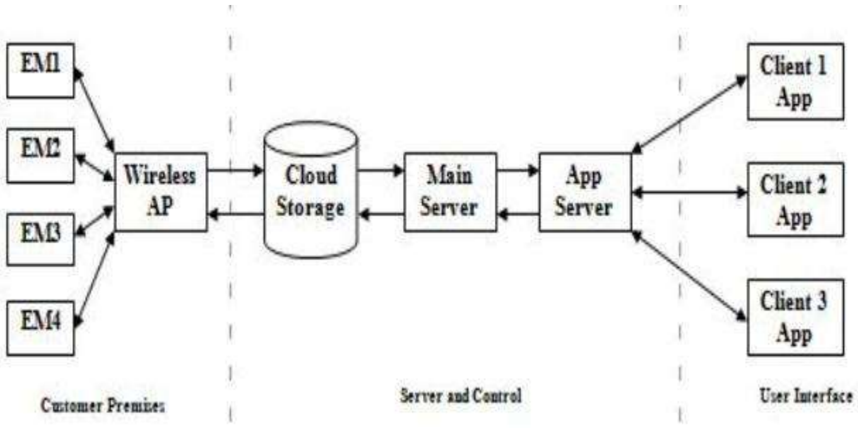


Plate VI: System Architecture (Karthikeyan, 2017)

Implementation of this system reduces manpower involvement in assessing the energy readings and the error caused by human readings. Improvement on this work can be used to analyze power distribution to an area and of cause the existing meter used in this work uses a current transformer method for sensing current. Pan *et al.* (2015) proposed an internet of things frame work for smart energy in buildings. The paper makes use of smart phones platform and cloud computing technologies to enable multi scale energy proportionality involving building, end users, and organization-level energy variation. The proposed system proves significant economic benefits in terms of energy conservation, and global sustainability. Jadhav & Rajalakshmi, (2017) proposed a compact low cost IoT enable smart and secure power monitor. This system utilizes AES encryption power monitoring sensor with Wi-Fi capabilities. Power consumption data is acquired using current sensor and energy meter modules. The results are uploaded on the web pages, which can be accessed through a remote login and android app.

Yaqoob *et al.* (2017) Investigated, highlighted, and reported premier research on advances made in IoT architecture recently. This paper classified IoT architectures and devised a taxonomy based on important parameters such as applications, enabling technologies, business objectives, architectural requirements, network topologies, and IoT platform architecture types (centralized and distributed). The authors also predicted key requirements for future IoT architecture which should be scalable, flexible, energy efficient, interoperable, and secure network architectures will be required, as the existing ones can only support a limited number of devices.

With all the literature reviewed above, it became obvious that many literature used the conventional series resistance method and current transformer method to measure and monitor current flow through a load, the two method has a limitation of not very convenient to install. To the best of our knowledge, IoT is the best technology to employ to an efficient power management system. Introducing a contactless current sensor to an IoT board so as to measure flow of current through a load becomes necessary. This will in turn ease the process of installation for the device. Also monitoring the presence of human being in the building will go a long way in making an efficient energy management system. This therefore justify the need for this research work.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Preamble

This chapter present the materials and methodology used in achieving the set objectives for this research work, the detail methodology of objective one which is the development of IoT device to measure and control power, objective two which is the development of IoT based human detection device, also included was the development of IoT based bidirectional counter which was used to aid the efficiency of the human detection device, and objective three which was the development and implementation of the web application that was used to gather data coming from all the IoT devices that was built. After undergoing thorough research and feasibility study based on the proposed IoT efficient energy management and control system it was concluded that the construction of the IoT devices be actualized by developing the IoT.

3.2 Materials

The materials used for the successful completion of this research work can be categorized into hardware and software part and are listed as follows:

3.2.1 Hardware: The hardware materials and components used in this project are listed.

1. Electronics component such as ESP8266 modules, AVR microcontrollers, voltage sensor, current sensor, human detection sensor, switching relay, resistors, capacitors, transistors, soldering iron, soldering lead and variable resistors.
2. TOP programmer which was used to burn the code on the AVR microcontrollers.
3. HP PC with the following specifications:
    i. Device name: HP-PC
    ii. Processor: Intel (R) core (TM) i3-2310M CPU @ 2.1GHz

iii. Installed Ram: 4.00GB

iv. Device ID: 00426-OEM 8992662-400

v. System Type: 32-bit operating system, x32-based processor, running on window 7 Ultimate.

3.2.2 Software: The software materials used in this project is listed below

1. AVR studio IDE, used to develop and debug the microcontroller C++ code
2. Visual Studio code IDE, used to develop the PHP and HTML/CSS code for the web application.

3.3 Methodology

The steps taken in this research work is presented in Figure 3.1 while Figure 3.2 shows the graphical representation of the overall system developed.

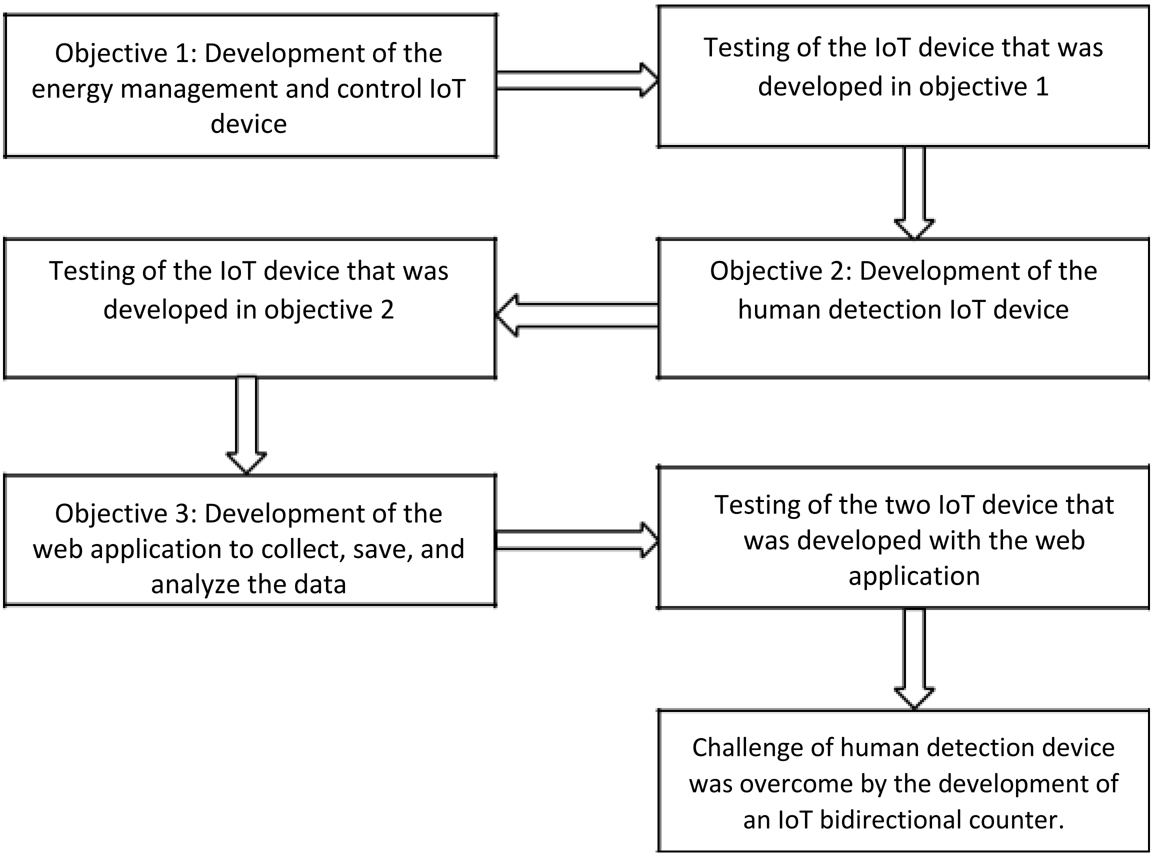


Figure 3.1: Work Flow for the Research.

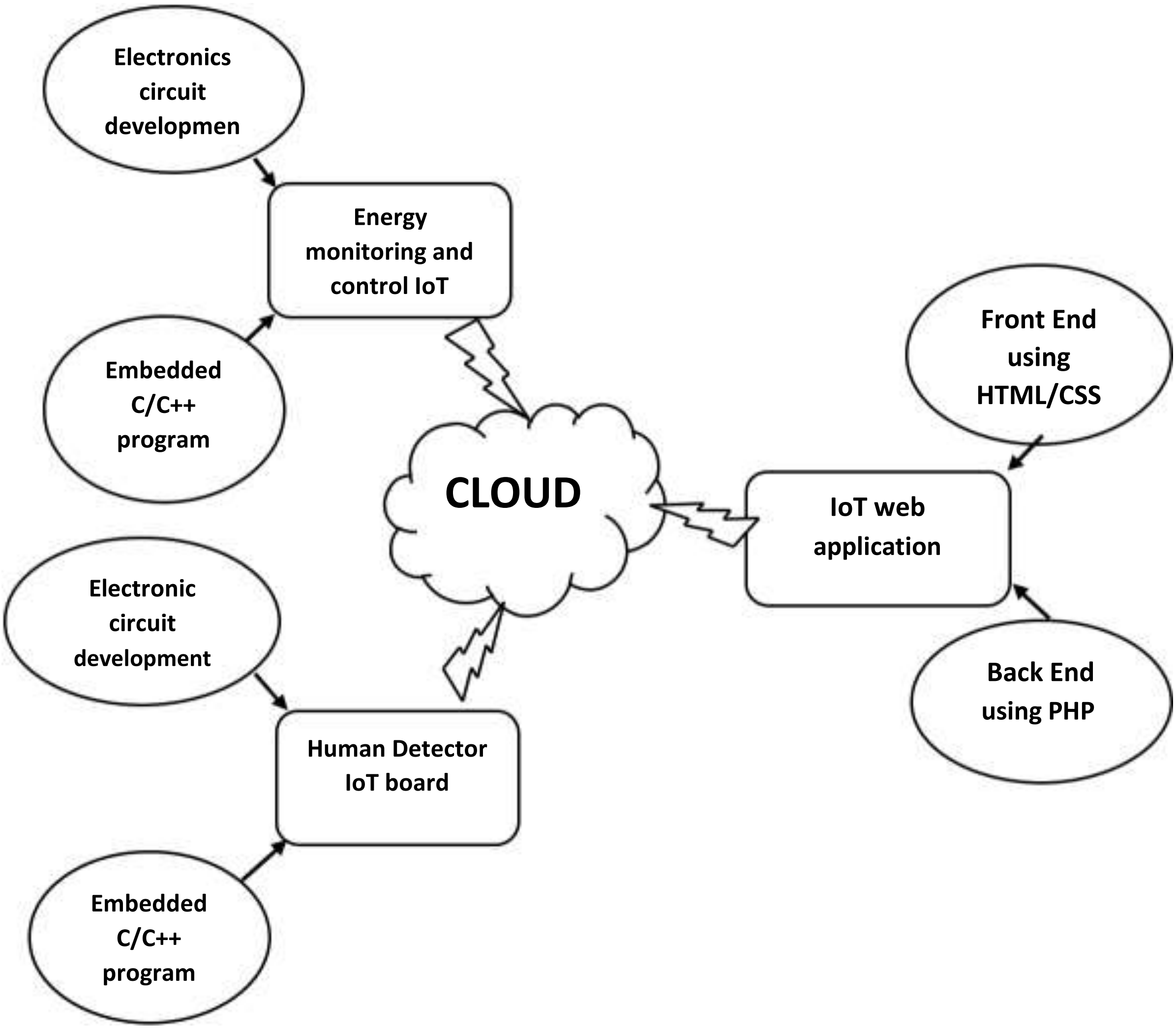


Figure 3.2: Systems Organization

The entire system was implemented based on the following methodology.

3.3.1 Development of a contactless IoT based energy measurement and control system (Objective 1)

This device was developed in six building blocks which are power supply unit, microcontroller unit (ATMEGA328), current sensor unit (contactless current sensor), voltage sensor unit (voltage divider network), 30A relay unit, Wi-Fi module (ESP8266). The blocks put together was responsible for energy measurement through the voltage sensor and the current sensor, while the relay help with the control of the load, and the ESP8266 help in the connection to the internet through the wireless modem (gateway). The block diagram for objective 1 is shown in Figure 3.3

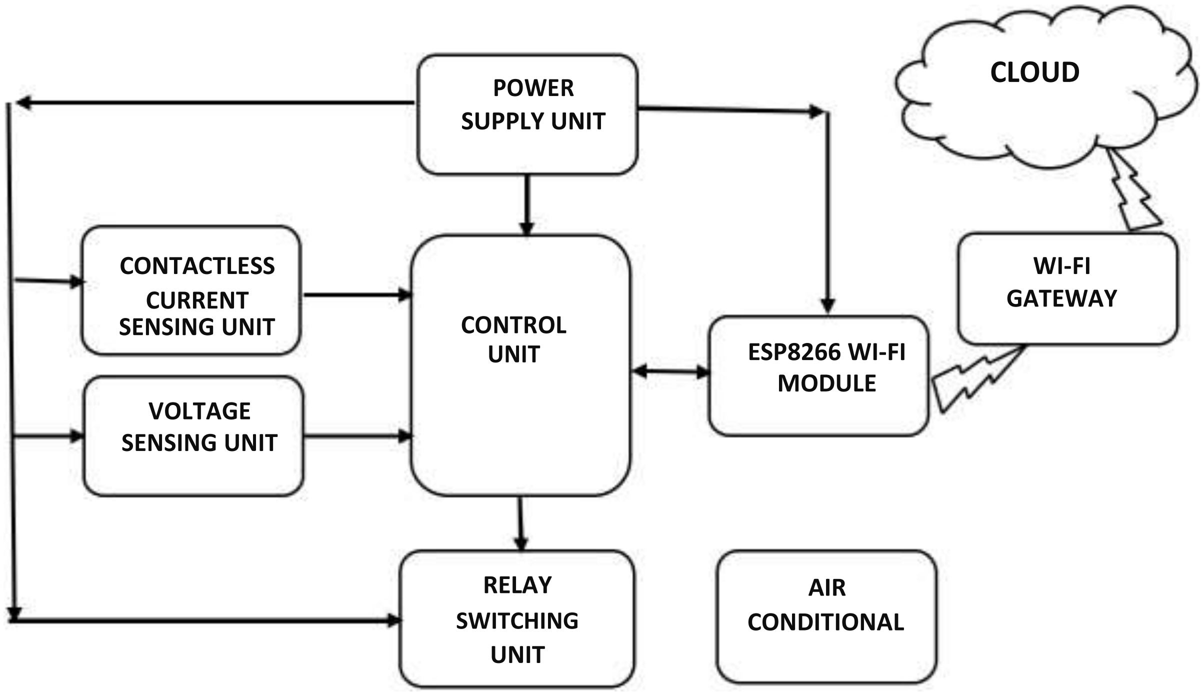


Figure 3.3: Block Diagram for the Power Efficient Contactless IoT Board

3.3.1.1 Power Supply Unit:

This unit is responsible for supplying a steady 5V DC and 3.3V DC power supply to every other subunit in other to perform their function, it makes use of a step down transformer which step the 220V AC supply down to a 12V AC, a bridge rectifier which comprises of 4 power diodes IN4007 that rectify the AC signal into a DC signal, a filtering capacitor that filters out the AC ripples and finally the voltage regulators that regulate the filtered DC signal to a steady 5V and 3.3V respectively. Figure 3.4 show the circuit diagram of the power supply unit.

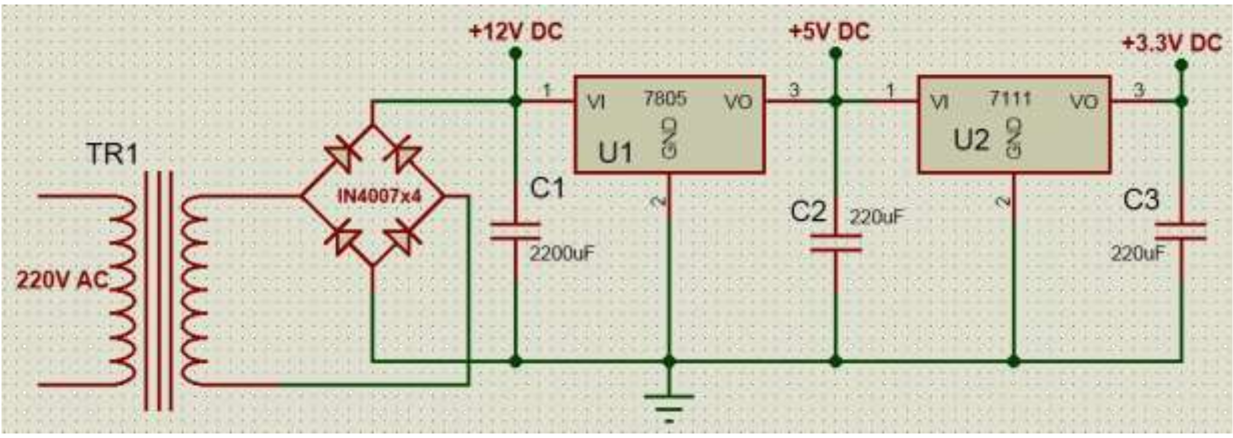


Figure 3.4: Circuit Diagram for the Power Supply Unit

Design Calculations for the Filtering capacitor selection

For this unit to work as expected, the choice of the filter capacitor is dependent on the output current from the transformer. The rectified dc voltages ( ) the load current ( ) and the filter capacitors are related

Thus: For a full-wave rectifier,

$$= \frac{-}{(4\sqrt{3})} \qquad (3.1)$$

Where is ripple factor =5%, is load current = 500mA, f = 50Hz, is rectifier voltage

= 12V

$$= \frac{-}{(4\sqrt{3})} \qquad (3.2)$$

$$= \frac{0.5}{(4\sqrt{3})\ 50 \quad - \quad 0.05 \quad 12}$$

$$, =_1 = \frac{0.5}{207.846096} = 0.002405626 = 2406$$

$_1$ Is selected to be 2200 while 220 is selected for $_2$ and $_3$ in other to filter any noise at the 5V output of the IC7805 regulator and the 3.3V output of the LM7111 regulator.

3.3.1.2 Voltage Sensor Unit:

This unit is made up of a voltage divider network which takes it source from the rectified and filtered DC signal from the transformer, the output of the network is fed to the ADC of the microcontroller for further processing.

The transformer input was stepped down with a constant stepping ratio of

$$\frac{}{} = \frac{220}{12} = 18.33$$

Since the inbuilt ADC of the microcontroller can only handle a maximum voltage of 5V DC, and the unregulated voltage in the circuit is 12V DC, this is the reason why the voltage was scale down to a voltage that will not be harmful to the microcontroller, the circuit is shown in Figure 3.5

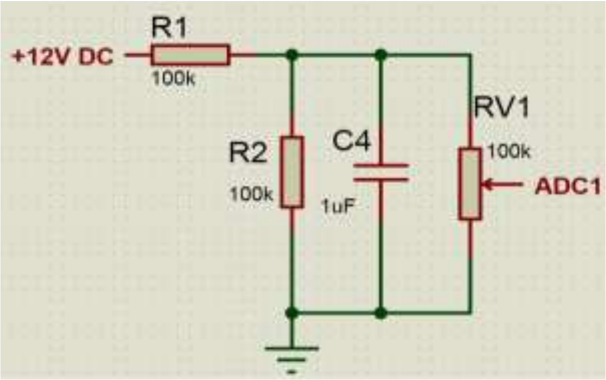


Figure 3.5: the Voltage Sensor Unit

R2 and RV1 are connected in parallel and have equal resistance of 100K ohms which make their equivalent resistance, RT to be:

$$= \frac{100 * 100}{100 + 100} = 50$$

Using the voltage divider theorem

$$V_{ADC} = \frac{50 * 12}{100 + 50} = 4$$

A constant of 12V/ 4V = 3 was noted when the unregulated 12V was scaled down to 4V using the voltage divider network, and also a constant of 18.33 from the transformer was both return to the equation codded in the C++ program running on the microcontroller in other to get the actual voltage at the AC input to the load which was used to estimate the power consumption for the load.

3.3.1.3 Current Sensing Unit:

This unit senses the current flowing through the load contactlessly. The sensor that was employ in this unit is **MLX91205, i**t is a single axis magnetic field sensor based on the Hall Effect. It is an integrated combination of CMOS Hall circuit and slim ferromagnetic hub. The CMOS circuit contains two pairs of Hall elements, the direction of sensitivity of which is parallel to the surface of the chip. The ferromagnetic concentrator amplifies the external magnetic field and concentrates it on the Hall element. The

MLX91205 is well suited for current sensing in AC and DC applications. It produces a proportional, linear, analog output voltage that is proportional to the external magnetic field parallel to the surface of the chip. The circuit is manufactured using a standard CMOS process and a ferromagnetic layer is added in a simple post-processing step. The monolithic device includes Hall element, offset cancellation circuit, current source, chopper stabilized amplifier circuit, and parameter programming capability. With dynamic compensation cancellation, any compensation voltage caused by temperature changes, package stress, or other factors will be greatly reduced. Therefore, the device has an extremely stable signal output, which is not affected by mechanical stress and is hardly affected by temperature.(*MELEXIS MLX91205, datasheet*). Figure 3.6 shows the offset over temperature while Figure 3.7 shows the sensitivity over temperature.

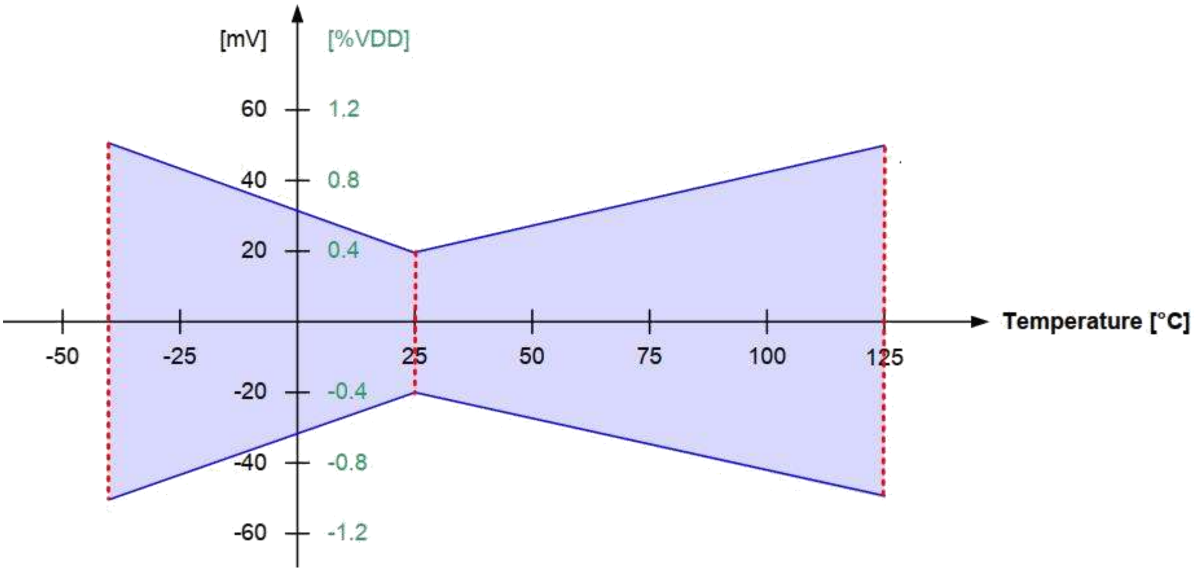


Figure 3.6: MLX91205 Offset Over Temperature (*MELEXIS MLX91205, datasheet.)*

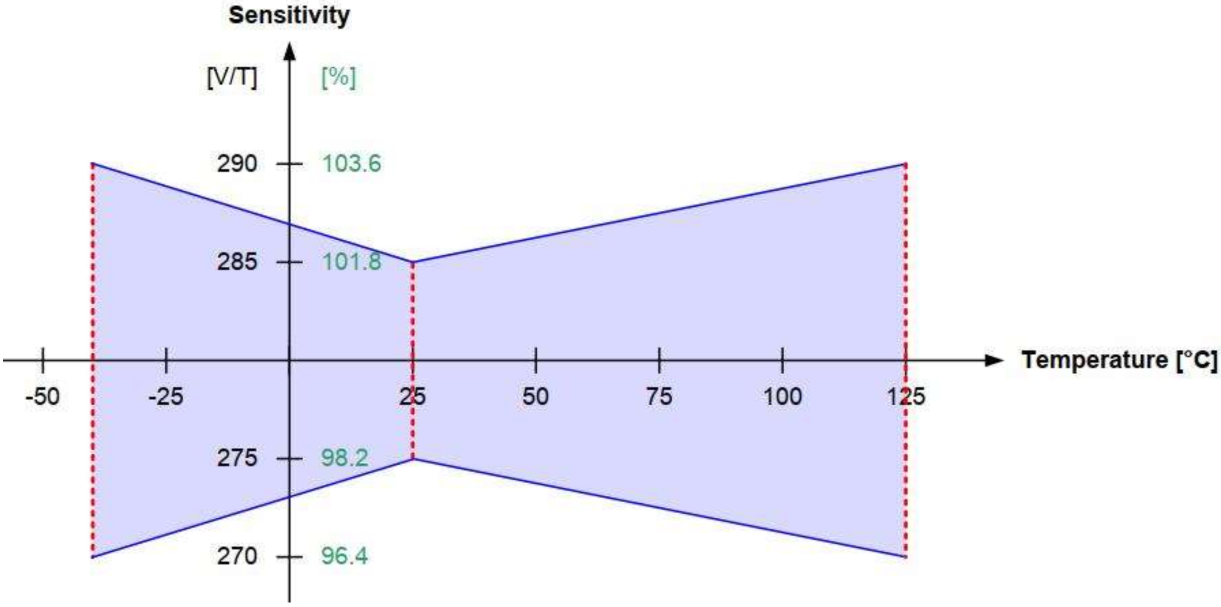


Figure 3.7: MLX91205 Sensitivity Over Temperature (*MELEXIS MLX91205, datasheet)*

The sensor can be applied on low current measurement i.e. for current less than 2A, and medium current measurement i.e. for current less than 30A and also on high current measurement i.e. for current less than 600A, but for this project work the medium range was selected since it was applied on current load below 30A as we only target the Air conditional terminal in the building, which was certain not to exceed 30A. Figure 3.8

shows the sensor configuration for medium current sensing while Figure 3.9 shows the circuit diagram for the medium current sensing of the MLX91205.

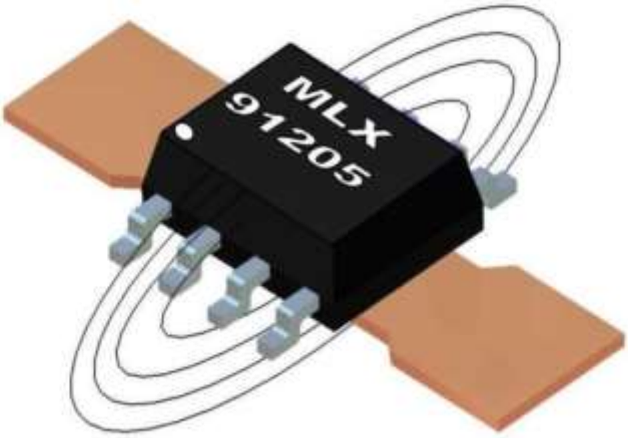


Figure 3.8: MLX91205 Medium Current Sensing Configuration (*MELEXIS MLX91205, datasheet)*

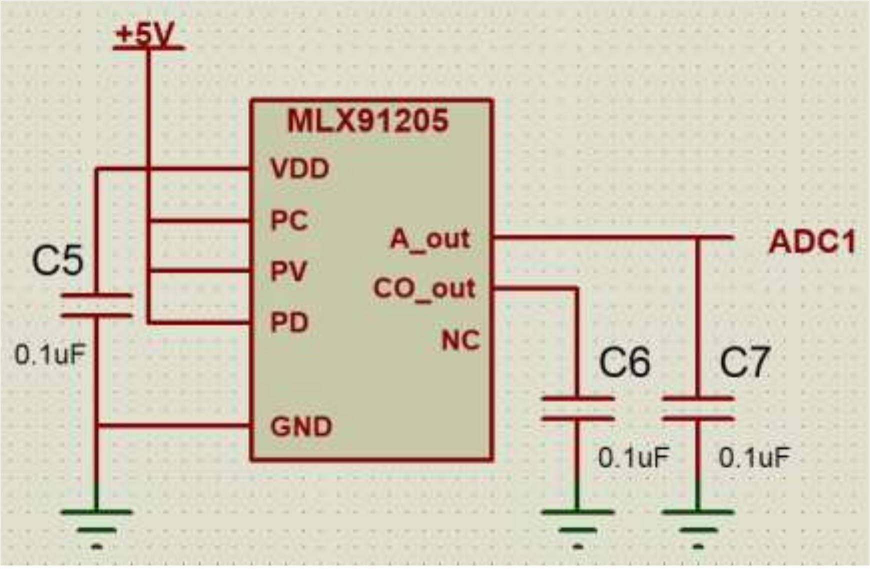


Figure 3.9: Circuit Diagram for the Contactless Voltage Sensor

3.3.1.4 Control Unit:

The control unit consist of both hardware and software, where the hardware is the electronics component and the software is the program that controls the electronics.

1. **Control Unit Hardware**: The Advance Virtual RISC (AVR) microcontroller family ATMEGA328P was employed for this operation, it is a low cost microcontroller with speed of 20MIPS at 20MHz, internal flash memory of 32KB, internal RAM of 2KB, internal EEPROM of 1KB, 8 channel 10bit ADC and a small size microcontroller, it perform the control functions of the IoT Board. It read the analog signal from the magnetic current sensor and measure current through the connected load using the Hall Effect phenomena (change in magnetic field). The AVR microcontroller converts the analog signal to a digital signal, it also measure voltage from the voltage sensing unit and converts it to digital value through its inbuilt ADC. It then calculate the power consumed by the connected load using the voltage and current gotten from both sensors, then transmits the voltage, current and power value to the cloud through the low cost, small size Wi-Fi module with the help of the inbuilt Universal Serial Asynchronous Receive Transmit (USART) communication protocol.

2. **Control Unit Software**: The software part is the embedded C++ code written to control the hardware. The code was written using AVR Studio. AVR Studio is an Integrated Development Environment (IDE) developed by Atmel Corporation with a vast C/C++ library that support all AVR families of microcontrollers. The AVR Studio help debug the embedded C++ code and make the code free from logic and syntax error and finally generate the machine code (HEX File) required by the microcontrollers internal processor to operate. The embedded C++ code handles the serial communication between the microcontroller and the Wi-Fi module both the communication protocol i.e. USART and the speed of communication (BAUD Rate). The code also perform the switching of the relay through a BJT transistor so as to be able to automatically and manually control the load and as well configure the internal ADC of the microcontroller to read data from the voltage sensor and current sensor. The HEX file generated was uploaded on the

microcontroller through the use of TOPWIN Universal programmer. Figure 3.10 show the block diagram of the control unit, Plate VII show the image of the microcontroller used while Plate VIII show the AVR Studio environment used for the embedded C++ code.

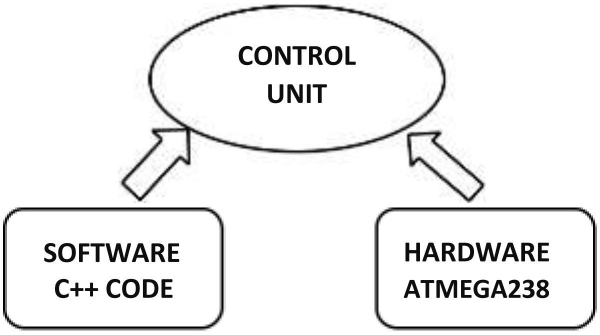
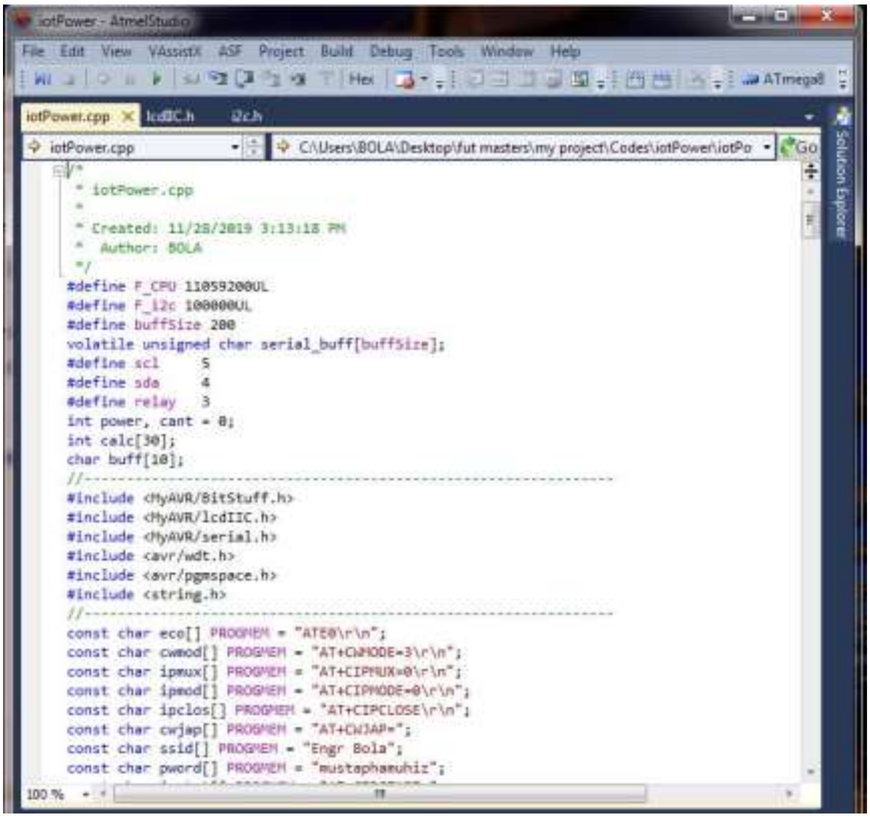


Figure 3.10: Block Diagram of the Control Unit

Plate VII: Image of ATMEGA328



```
/*
 * iotPower.cpp
 *
 * Created: 11/28/2019 3:13:18 PM
 *  Author: BOLA
 */
#define F_CPU 11059200UL
#define F_i2c 100000UL
#define buffSize 200
volatile unsigned char serial_buff[buffSize];
#define scl     5
#define sda     4
#define relay   3
int power, cant = 0;
int calc[30];
char buff[10];
//-------------------------------------------------------------
#include <MyAVR/BitStuff.h>
#include <MyAVR/lcdIIC.h>
#include <MyAVR/serial.h>
#include <avr/wdt.h>
#include <avr/pgmspace.h>
#include <string.h>
//-------------------------------------------------------------
const char eco[] PROGMEM = "ATE0\r\n";
const char cwmod[] PROGMEM = "AT+CWMODE=3\r\n";
const char ipmux[] PROGMEM = "AT+CIPMUX=0\r\n";
const char ipmod[] PROGMEM = "AT+CIPMODE=0\r\n";
const char ipclos[] PROGMEM = "AT+CIPCLOSE\r\n";
const char cwjap[] PROGMEM = "AT+CWJAP=";
const char ssid[] PROGMEM = "Engr Bola";
const char pword[] PROGMEM = "mustaphamuhiz";
```

Plate VIII: AVR Studio IDE Used for the Embedded C++ Code.

3.3.1.5 Wi-Fi Module (ESP8266):

ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP protocol stack and microcontroller capability produced by Shanghai-based Chinese manufacturer Espressif Systems. It Is used in this project to communicate with the IoT server through the gateway, the module was interfaced with the microcontroller directly and it operate on 3.3V DC. Plate IX shows the ESP8266 Wi-Fi module

Plate IX: ESP8266 Wi-Fi Module

3.3.1.6 Relay Switching:

An electromechanical relay was used in this project because of its electrical isolation of its pole i.e. normally close (NC), the normally open (NC) and the common. A 12V, 30A relay was used and a BJT transistor was used for the switching. When the 12V supply voltage is delivered to the relay coil, current flows through the coil and a magnetic field would be produced around the coil which makes the common to disconnect from the NC and connect to the NO. When power is removed from the relay, the magnetic field generated by the coil collapse and produces a fairly high voltage in the opposite direction, it is called inductive spike. This inductive spike voltage can damage the driver transistor and thus reverse-biased diodes (also known as the anti-parallel diode) was connected across the coil to "short-out" the induction spike when it occurs. Since a relay requires 12V to operate, the transistor was used to amplify the voltage and current being supplied by the microcontroller to the relay. The calculations behind the values chosen for the base resistance so as to bias the transistor accurately is as follows:

$= \quad -$

$= \quad -$

$= 1000\Omega$

$= 12$

12

$_{1000} = 0.012$

$= 0.7 \quad (\qquad)$

$= 12$

$$= \frac{= 0.012}{12 - 0.7}$$

$\therefore \quad = 941.67\Omega$

(3.3)

(3.4)

(3.5)

Therefore a 1kilo ohms resistor was selected as the base resistor for the transistor. The circuit diagram is shown in Figure 3.11 and the complete circuit diagram for the power measurement and control IoT board was presented in Figure 3.12.

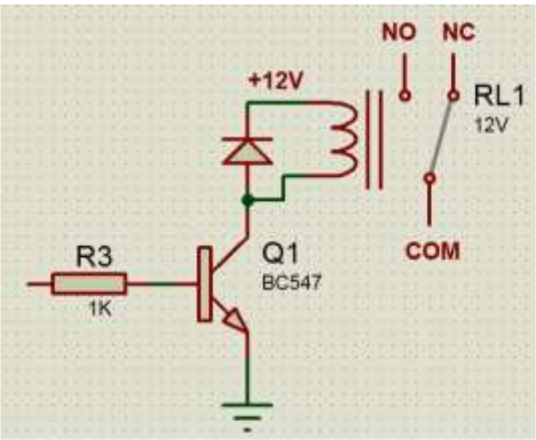


Figure 3.11: Relay Switching

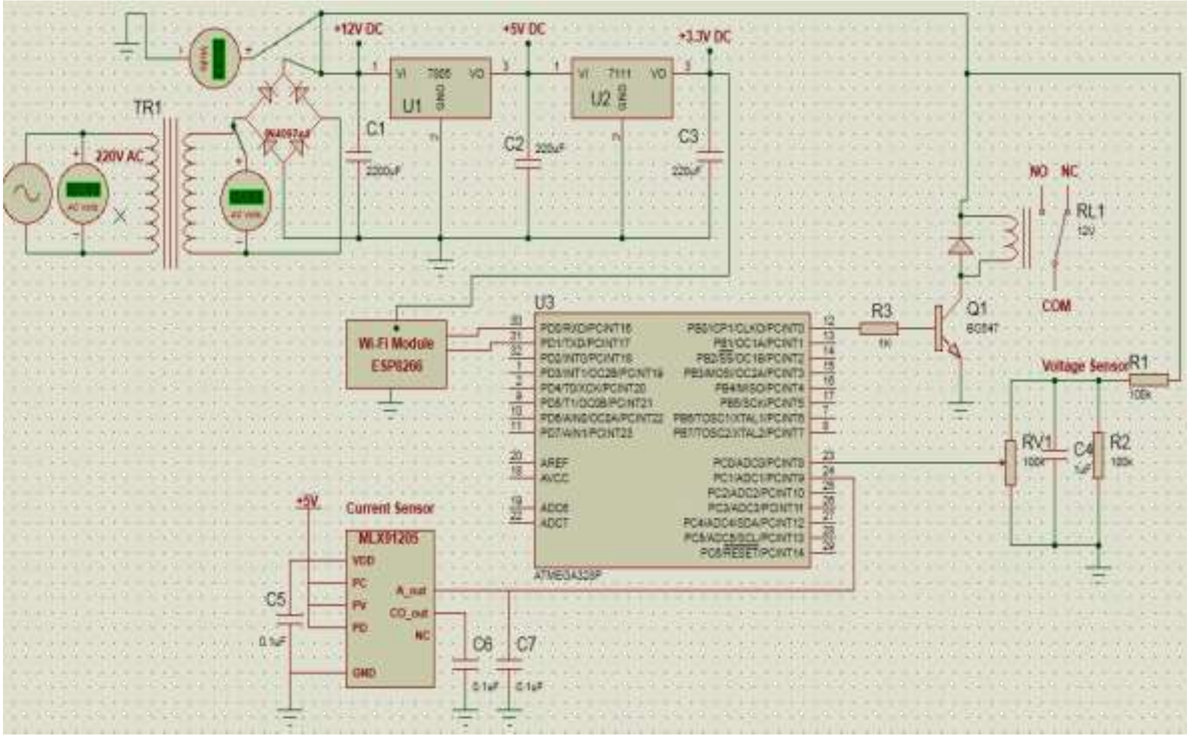


Figure 3.12: The complete Circuit Diagram for the IoT Board in Objective 1.

3.3.2 Development of an IoT based human detector device (Objective 2).

Objective two is achieved using AVR microcontroller, the low cost, high speed, small size ATMEGA328, which will perform the control function of the human detection IoT sensor. A MEM infrared sensor was used to sense human presence in the building, this sensor can detect and differentiate humans from other moving/stationary objects through the heat emitted from them, it then, sends the temperature data to the AVR microcontroller using the IIC communication protocol. The microcontroller will read the data from the MEM IR sensor and then send to the cloud through the low cost, small size Wi-Fi module. The power supply unit same as in Figure 3.4 was used, it also rectified AC to DC then filtered and regulates to a 3.3V and a 5V steady DC in other to power all the electronics component/modules. Figure 3.13 shows the block diagram of the proposed human detection IoT board.

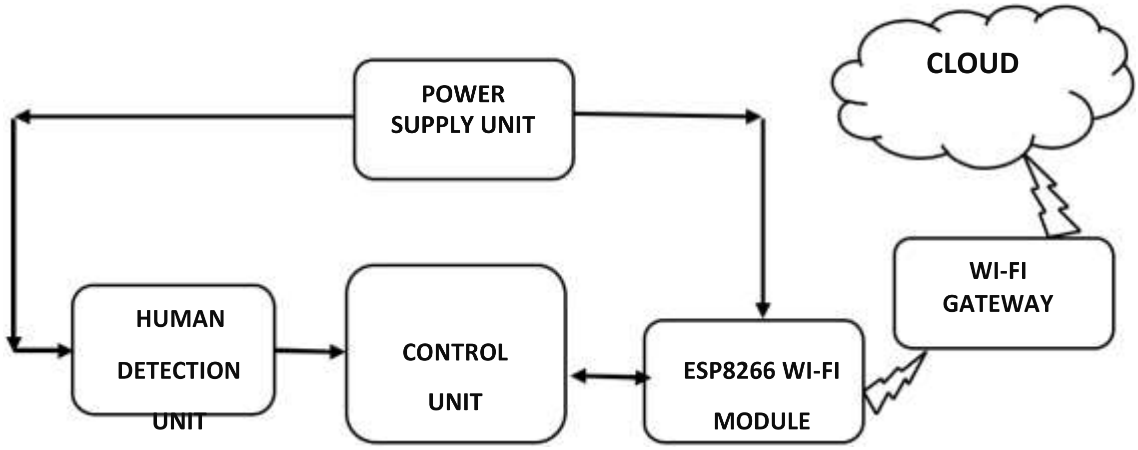


Figure 3.13: Human Detection IoT board Block Diagram

3.3.2.1 Human detection Unit:

The AMG8833 passively measures and send through IIC port, Thermal radiation from the gray body that emits infrared light. Temperature is calculated using Stefan Boltzman's law: $\prod = \varepsilon A \sigma T^4$ where ε is the emissivity (between 0 and 1), A is the surface area, σ is Stefan Boltzmann's constant, T is the temperature of the object and Π is the radiant power. The equation used to approximate the gray body temperature is as follows: $V \approx k\ (T_{obj}^4 - T_s^4)$ where V represents the voltage measured by the original sensor. The variable k is an empirical constant, which absorbs possible A, ε, σ and electronic noise. Ts is the temperature of the sensor itself and the remaining Tobj is the temperature of the measured object. The sensor temperature is subtracted to ensure that the sensor temperature does not deviate from the measured value of the object temperature. In order to obtain accurate temperature predictions, these sensors are usually calibrated with target materials at different temperatures to ensure that the k value is accurate. Once completed, the empirical equation for the temperature of the object can be realized.

$$T_{obj} \approx (V/k + T_s^4)^{1/4} \tag{3.6}$$

AMG was developed on Panasonic MEMS technology, which can measure temperature of the entire specified area without any contact; in other words, it is a "contact-less thermopile array sensor”. 64 pixels yield accurate temperature measurement over a viewing angle of 60° provided by a silicon lens. AMG8833 uses an I²C communication interface, enabling temperature measurements at speeds of 1 or 10 frames/sec. Plate X show the AMG8833 that was used in this project

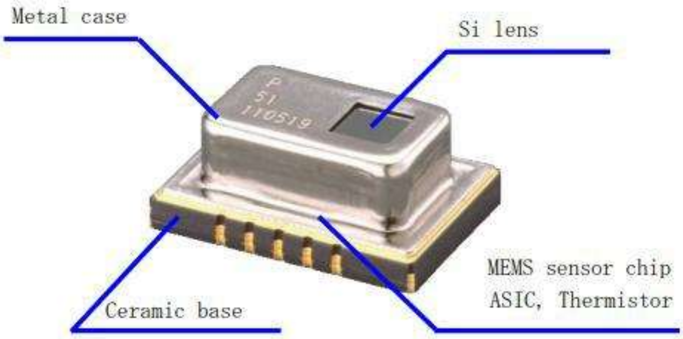


Plate X: AMG8833 Module *(AMG8833 datasheet)*

According to the manufacturer of the AMG8833, it can detect human both in motion and motionless, it detect temperature distribution by capturing the 8x8 pixel IR data, it can detect human from about 5meter away from the sensor and the closer the object is from the sensor the smaller the size of each pixel and the more accurate the temperature sensing will be, but for this project the 97.5cm pixel was selected so that the total coverage area will be 780cm by 780cm with the height of 750cm, since the module has 8 x 8 pixel. Plate XI shows the pixel calibration of the module.

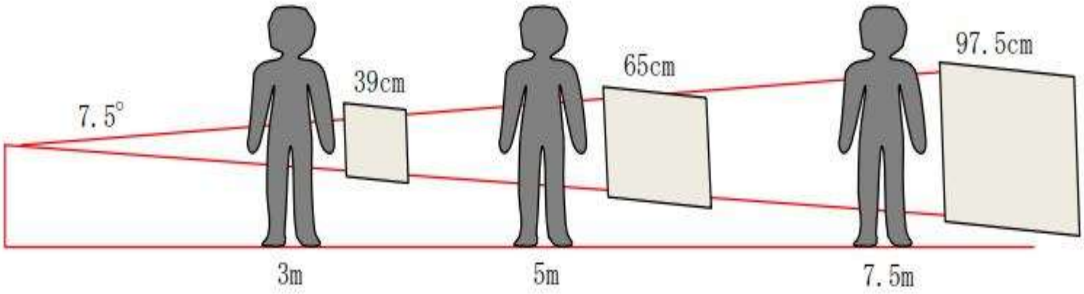


Plate XI: AMG8833 Pixel *(AMG8833 datasheet)*

The complete circuit diagram implemented for the human detection board is shown in Figure 3.14 (objective 2).

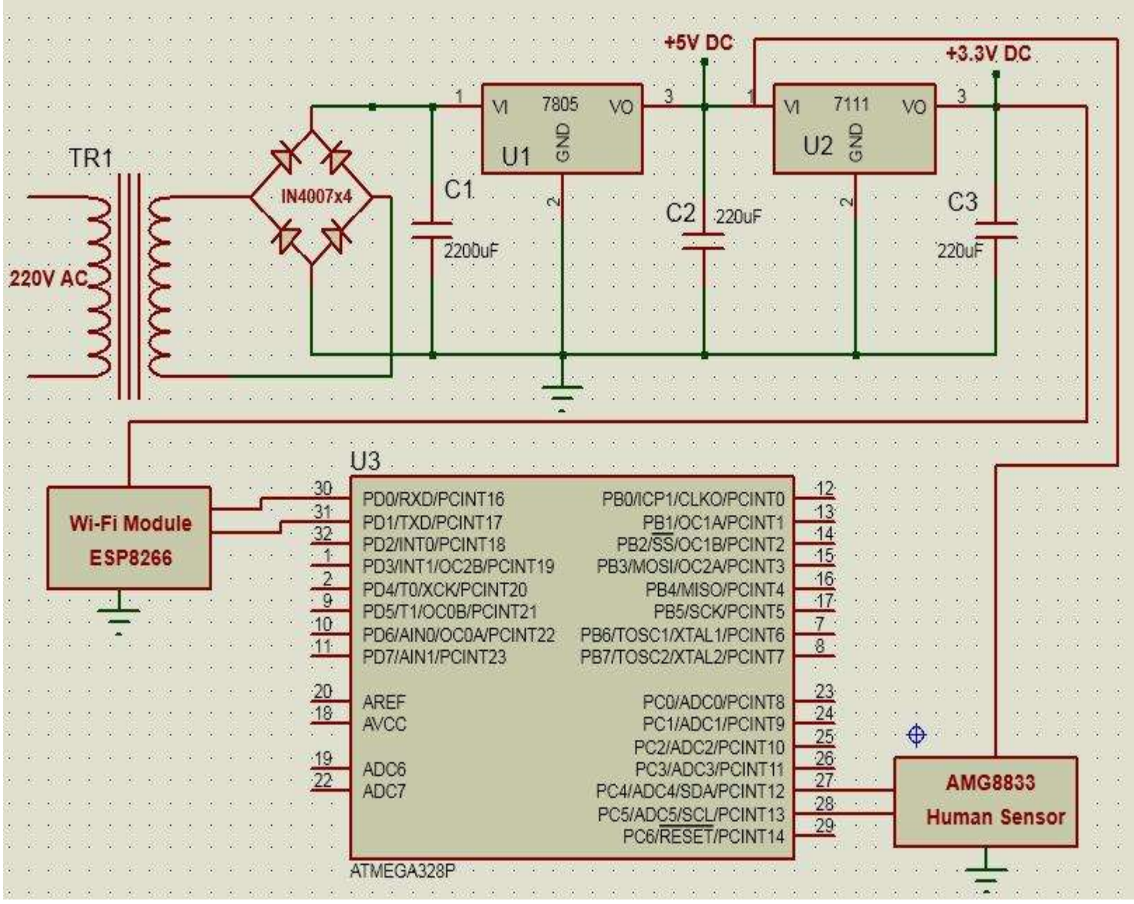


Figure 3.14: Complete Circuit Diagram for the Human Detection IoT Board

3.3.3 Development of web application (Objective 3)

The web application was developed in two modules, first is the front end (The user interface to view the power consumption of the connected load) The user interface which was develop using HTML and CSS, provide an avenue for every user to login to his or her dashboard with a unique user name and password, after logging in every user can view the power consumption history, switch between manual and automatic mode of operation, which when in manual mode user can manually switch the load on and off from the server and when in auto mode the server uses the temperature data generated from the human detection IoT board to determine if someone is in the room. When no one is in, the server sends signal to the power monitoring IoT device in other to power off the connected load. The second module is the back end code (Server side) which is responsible for sending data to the two IoT devices, and receiving data from the database and giving necessary command to the IoT devices. This was developed using PHP. The building blocks for the web application is shown in Figure 3.15 and the flow chart of the web application is shown in Figure 3.16

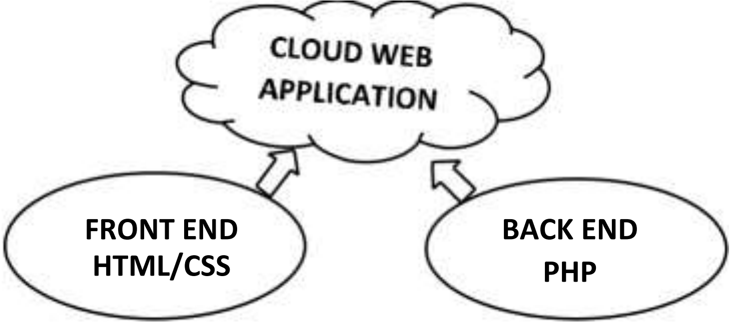


Figure 3.15: Building Blocks for the Web Application

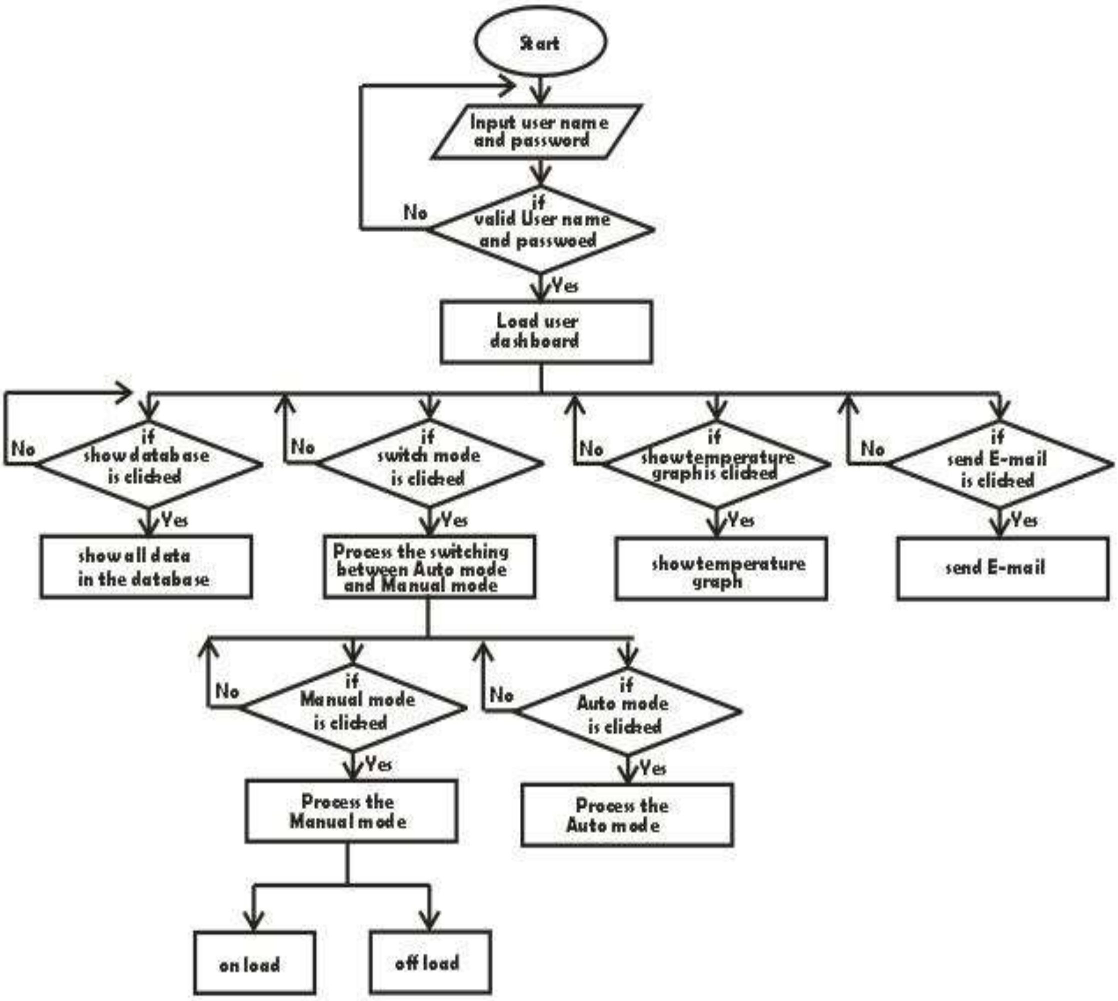


Figure 3.16: Flow Chart for the Web Application.

3.3.3.1 Communication with the Server:

Two major communication protocols were employed for communicating with the server in this project. The protocols are HTTP and TCP/IP protocol. The basic processing steps that the HTTP (Web) server performs are that the HTTP client uses the TCP transfer protocol to contact the Web server and request content. The client opens a TCP connection to the server and transmits HTTP request headers that specify the content of the request. Static content is stored on the server in the form of a disk file, while dynamic content is generated by the helper application that runs on the server according to the request. Once the server gets the requested content, it transmits an HTTP response header on the client's TCP connection, followed by the requested data (if applicable), but this project the requested data was the data generated by the two IoT devices. The basic sequence steps to serve requests for static content are as follows:

1. **Accept client connections**: Accept incoming client connections by performing an accept operation on the server's listening socket. This will create a new socket associated with the client connection.
2. **The read request**: reads the HTTP request headers from the socket connected by the client and parses the requested URL and option headers.
3. **Find File**: checks the server's file system to see if the requested content file exists and if the client has the proper permissions. Get the size and time of the last modification of the file to include in the response header.
4. **Send Response Header:** Transmits HTTP response headers on the client connection connector.
5. **Read file**: Read data from a file or read part of data from a file, for larger files on the file system.

6. **Send data**: Transfer the requested content (or part of it) in the socket connected by the client. For larger files, repeat the "Read File" and "Send Data" steps until all requested content is transmitted. All these steps involve potentially blocking operations. If the expected data has not arrived from the client, you can block the operation of reading data from the socket or accepting the connection. If the TCP send buffer is full due to limited network capacity, writing to the socket may hang. The operation of testing the validity of the file (using start ()) or opening the file (using open ()) can be blocked until any required disk access is completed. Similarly, reading a file (using read()).

3.3.4 Testing and evaluation of the developed system (Objective 4).

The testing and evaluation was done using the Wi-Fi 4G modem and can also work with any wireless hotspot of any smart phone serving as the GATEWAY for communication with the cloud. The two IoT boards require the SSID and password of the modem before it can be connected and they both have a yellow LED that indicates successful connection to the Wi-Fi modem. The devices were tested for a reasonable time so as to verify that it is actually logging data to the cloud database. The human detection board was also used to control the load automatically so as to be sure human absence can actually power down the load. Though the challenge of low sensitivity was encountered, any time the room temperature goes below 17 degrees ,the human detection device do give false alert due to the low temperature and the distance of sensitivity. The challenge was overcome with the IoT based bidirectional counter that was later developed.

3.3.5 Bidirectional Counter: In other to achieve the aim of the project, a bidirectional counter was developed as the challenge of false trigger do occur when the room temperature falls below 16 degree, which is as a result of the human detection IoT device failure to detect at that temperature. Figure 3.17 show the block diagram while the circuit diagram is shown in Figure 3.18.

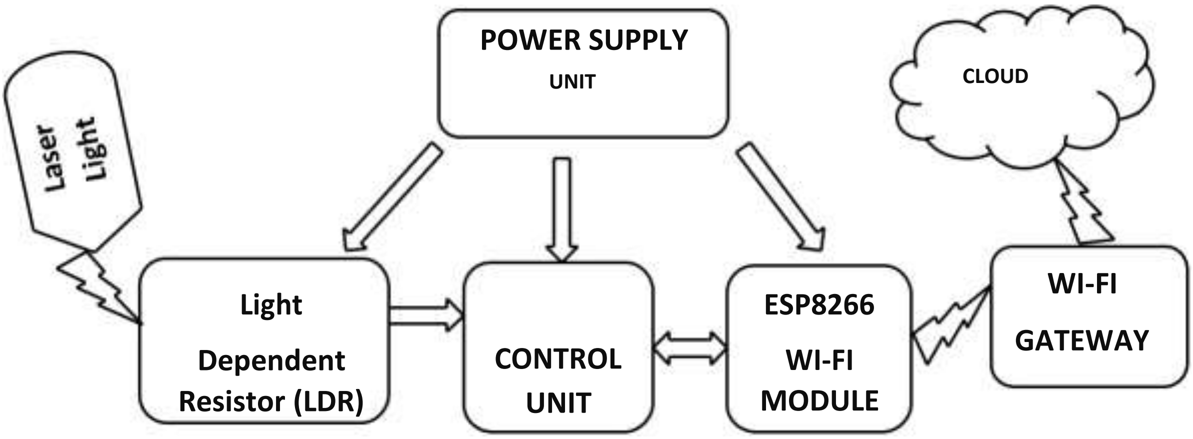


Figure 3.17: Block Diagram for the Bidirectional Counter

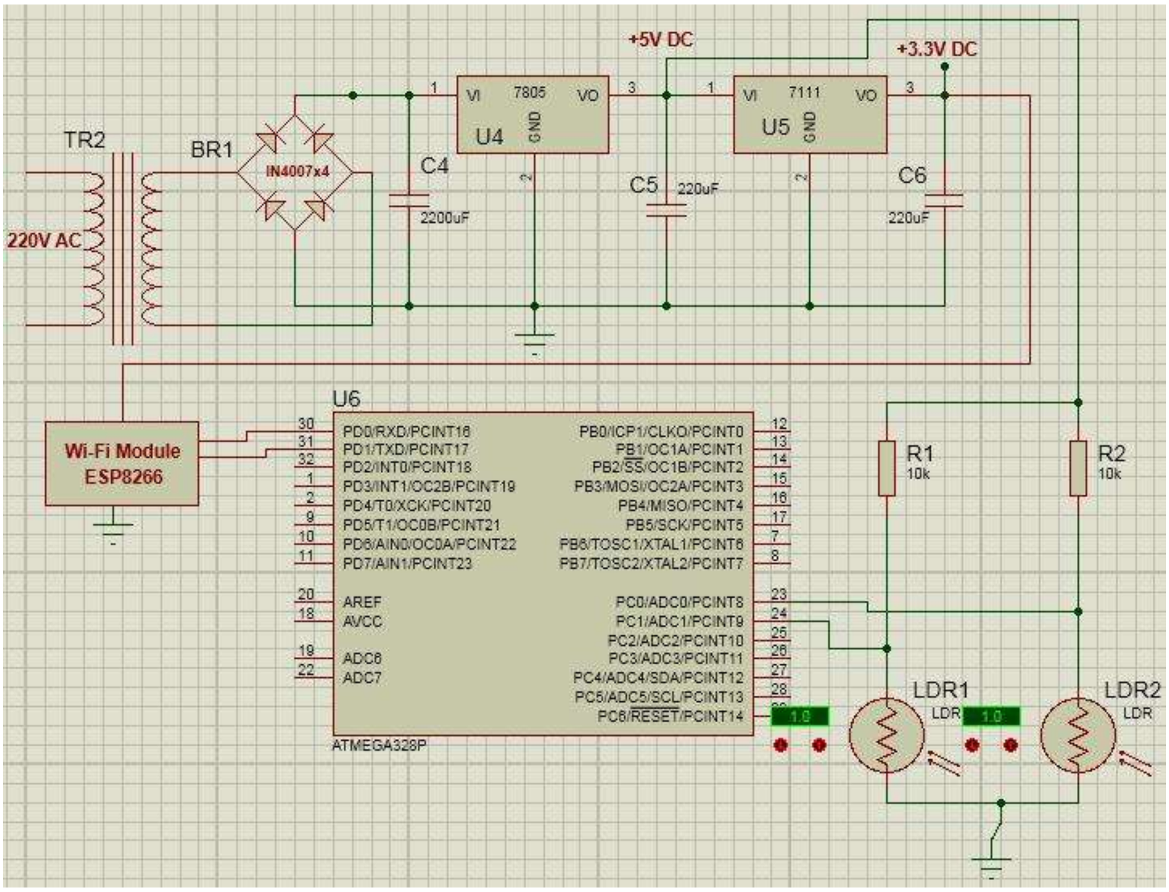


Figure 3.18: Circuit Diagram for the Bidirectional Counter

The bidirectional counter was achieved using two LDRs against two laser lights, the resistance of the LDR changes when the ray of light is bridged, because LDR is a kind of resistor that the resistance is inversely proportional to the intensity of light. The change in resistance caused by breaking of the laser light beam in turn causes a change in voltage. The voltage level change was determined by the internal ADC of the microcontroller. The microcontroller was programed to monitor both the LDRs simultaneously so as to know which one of them breaks first and which of the beam brakes last, the order of breaking the beam determines whether someone is entering or leaving the room. A register count is incremented when the direction is inward and decremented when the direction is outward. The microcontroller send message to the server whenever the register count is zero to switch off the AC and when the count is one or above to switch it on.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter captures the final outcome of the implemented system, the outcome of the development of both IoT devices i.e. the IoT energy monitoring and control device and the human monitoring IoT device. Furthermore, the test of the system and data obtained are evaluated to ensure that the objectives of the project were archived.

4.2 Result from the Power Monitoring and Control IoT Device Simulation

Proteus simulation software was used to simulate the designed circuit starting from the power supply unit to all the developed IoT device, as was shown in Figure 4.1, the following result was recorded from the software before proceeding to the final implementation of the system.

220V AC input source was inputted to the step down transformer which step it down to a 12V AC but the volt meter read 12.2V, and after the bridge rectifier the volt meter read 11.7V.

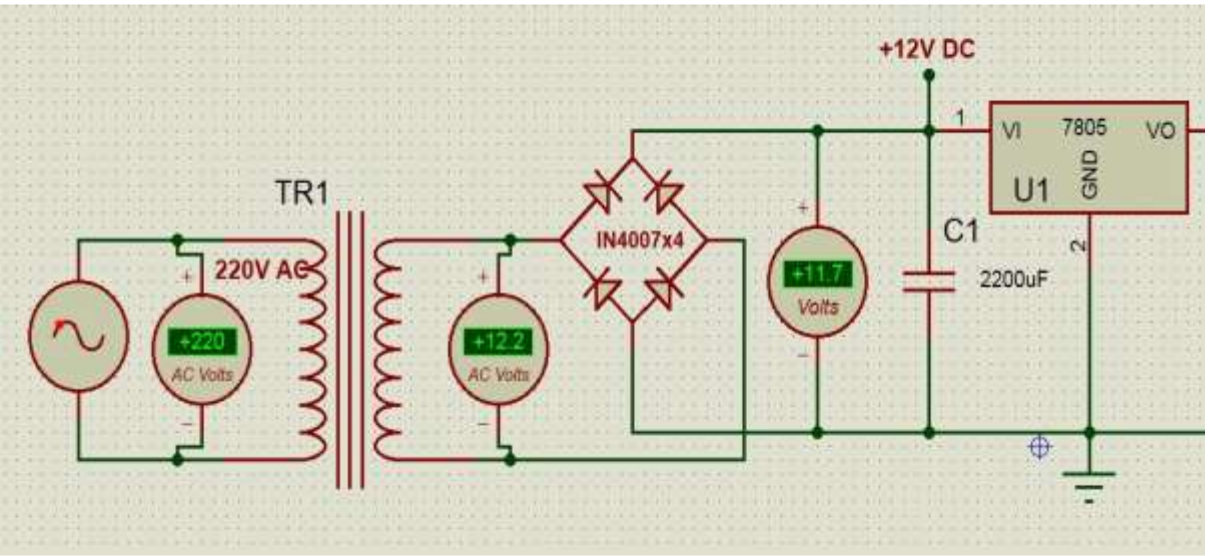


Figure 4.1: Power Supply Simulation A

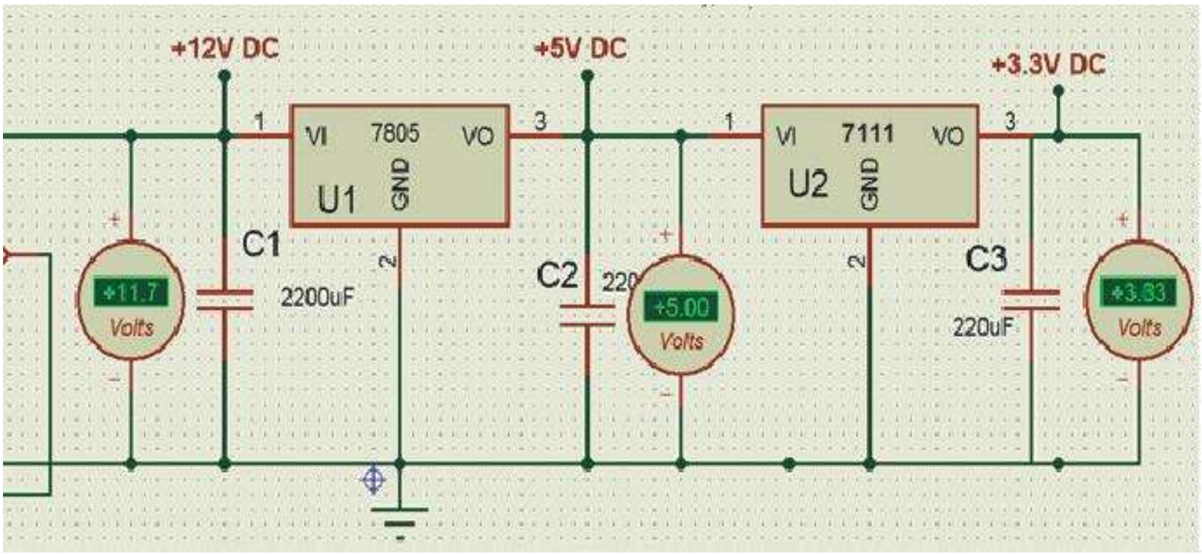


Figure 4.2: Power Supply Simulation B

Figure 4.1 and figure 4.2 show the simulation of the power supply on Proteus software, which indicate 220V AC supply from the source and was stepped down to 12.2V AC with the use of a step down transformer. The stepped down AC voltage was rectified with a bridge rectifier and the voltage after the rectification process was 11.7V. The voltage drop was due the biasing voltage drop by the diode used in the bridge rectifier. A 5V, voltage regulator was used and the output of the regulator was found to be 5.0V which was used to power the microcontroller. Also a 3.3V voltage regulator was used and the output was found to be 3.33V, which is also perfect to power the Wi-Fi module. The result from the simulation shows that the designed power supply circuit is good for the IoT devices.

Plate XII shows the power consumption monitoring IoT device after the permanent soldering and program was transfer to the microcontroller chip. It was tested and was found to be working fine before proceeding to the final packaging which, was shown in Plate XIII. It was packaged in a way that the load can be plug onto it without affecting the existing wiring network. It was packaged with a 15A socket because the target load was a 2Hp AC.

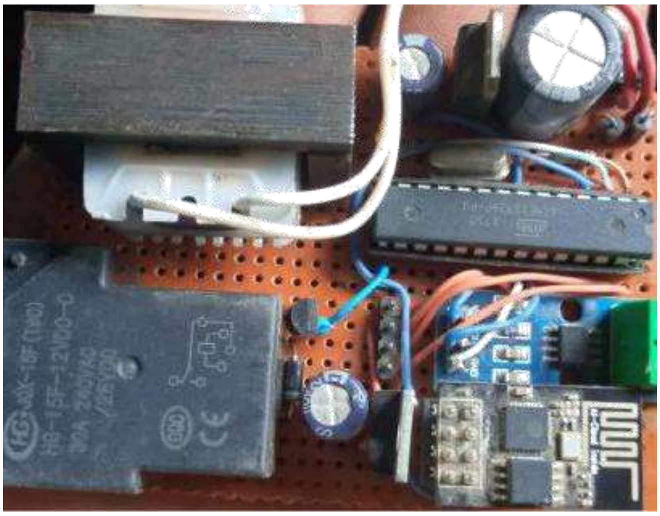


Plate XII: Complete IoT Board for Power Monitoring and Control

Plate XIII: Packaged IoT Board for Power Monitoring

4.3 Result from the human monitoring IoT device

The result gotten for the human monitoring IoT device was similar to that in Figure 4.1 and 4.2 since the power supply, wifi module and the microcontroller was the same, the IoT human sensing node was packaged in form of an energy saving bulb so as to ease the installation process and to have better focus of the room, Plate XIV shows the complete soldered board of the human detection IoT device after the permanent soldering, and the embedded C++ program was transfer to the microcontroller chip. Several tests such as continuity and voltage test were done, it performance was tested and was found working fine before proceeding to the final packaging which is shown in Plate XV.

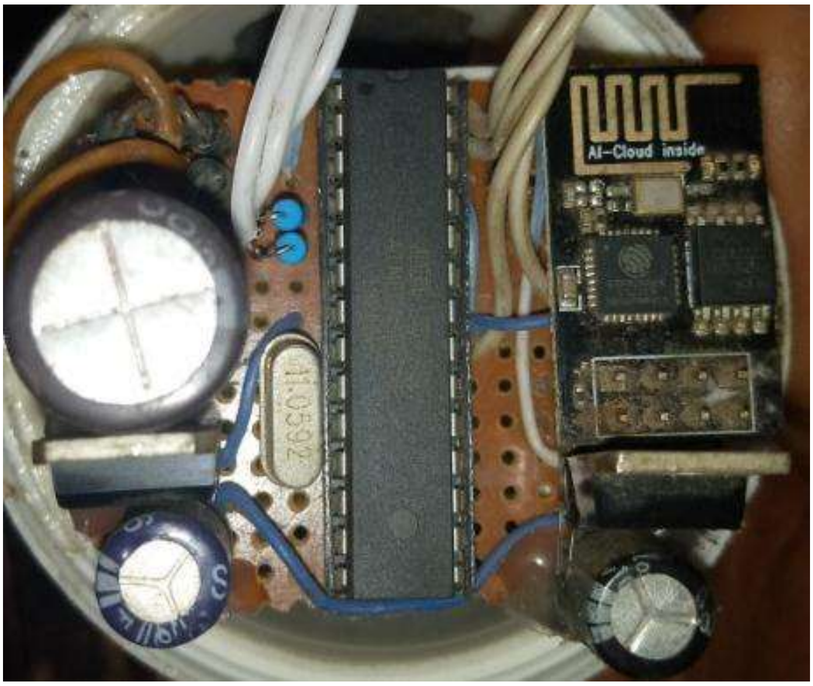


Plate XIV: Complete IoT Device for Human Monitoring

Plate XV: Packaged IoT Device for Human Monitoring

4.4 Result from the Web Application

Plate XVI shows the login page that first shows when trying to access the web server. It require a user name and password to proceed to each user dash board.

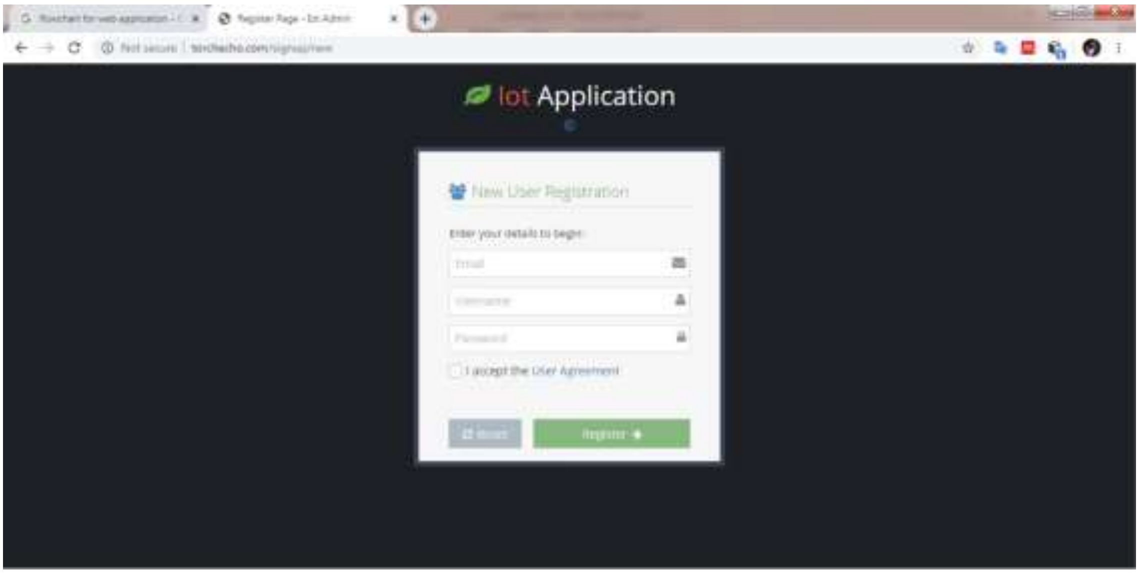


Plate XVI: Web Application Login Page

Plate XVII shows the dash board (home page) of a user that has successfully logged in.

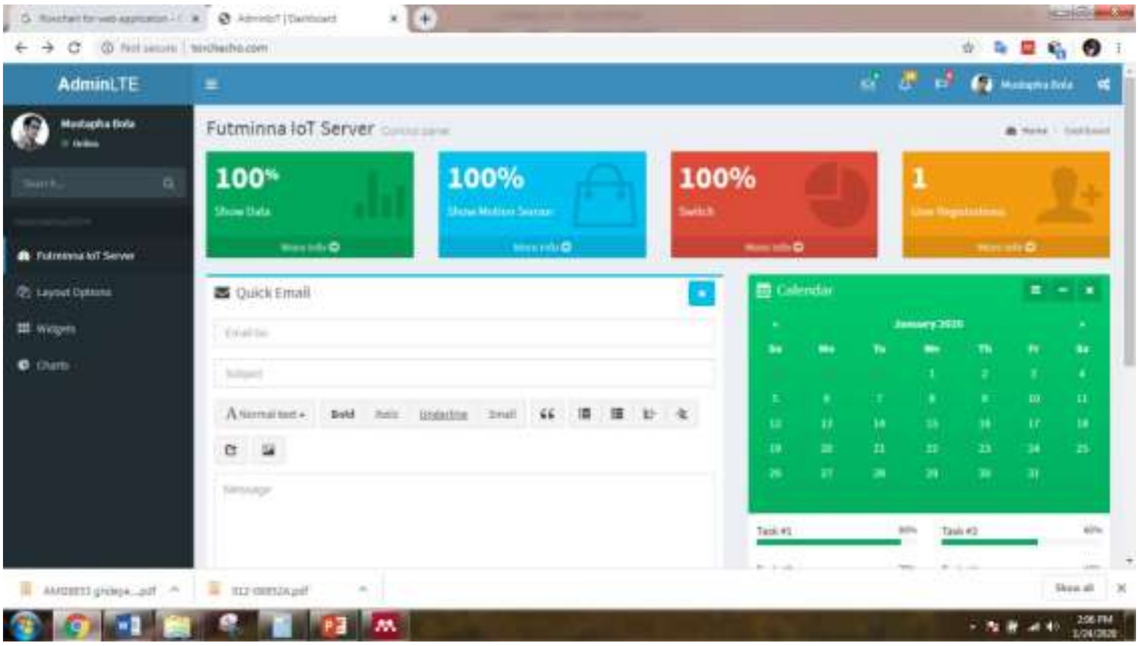


Plate XVII: Web Application Home Page

After logging in, each user has a unique ID which has been preprogram in the IoT nodes, every user has a dashboard where several operations can be performed e.g. switch between auto and manual mode. Manually switching on and off when operating in manual mode, check the temperature data, check the energy data in the database, check the plot of the voltage, current and power against time.

Plate XVIII shows the database that stores the voltage, current, power values and the time stamp as it was sent from the device, each data inserted in the database was attached with a time stamp which indicates the date and time that the data was received, large amount of data was saved as the device was left running for more than two month. The time delay in communication based on the time stamp was noted to be between 500 milliseconds and 2000 milliseconds depending on the network availability and the signal strength.

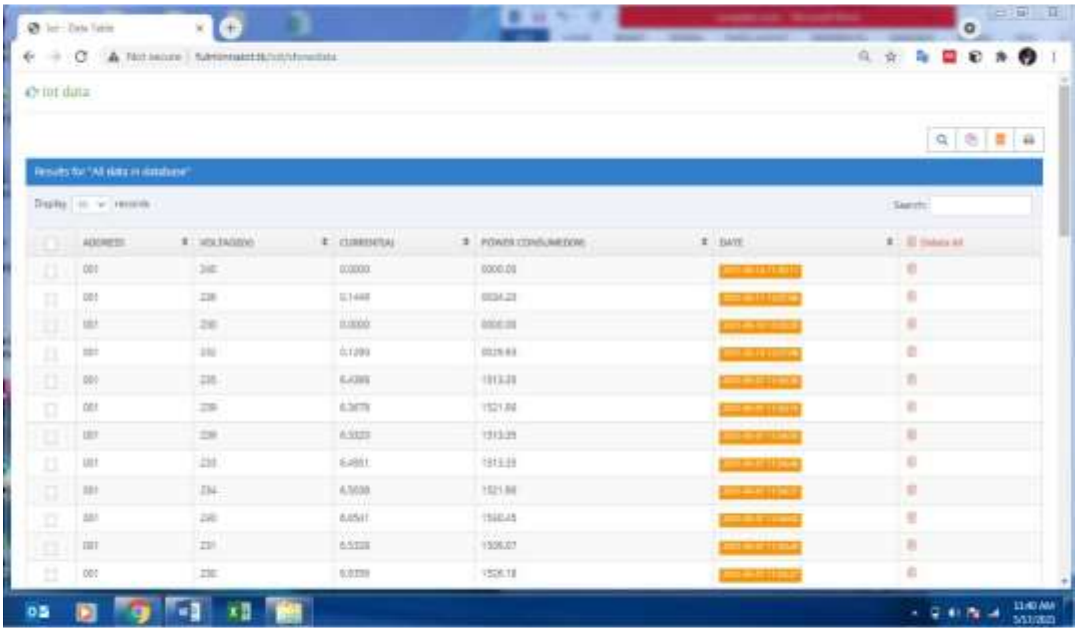


Plate XVIII: Web Application Database

Plate XIX shows the heat map which was generated from the human detection IoT board that sends the 64 floating point string gotten from the sensor to the server, this temperature values indicate when human being is in the office and when human being is not. The sensor readings become less accurate when the temperature of the room is below 27 degree and since the AC is the device being controlled the room temperature always go below 27 degrees, which was the reason the third IoT device was developed (Bidirectional Counter).

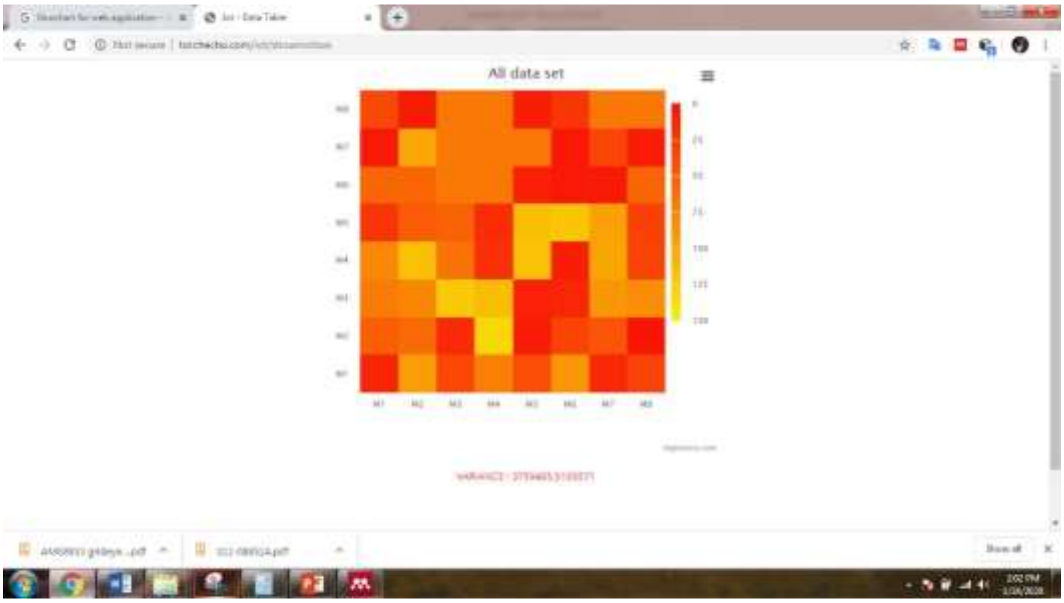


Plate XIX: Web Application Temperature Heat Map

Plate XX shows the button switch for switching between the auto mode and the manual mode while Plate XXI show the manual on and off button, which come active only when in manual mode of operation.

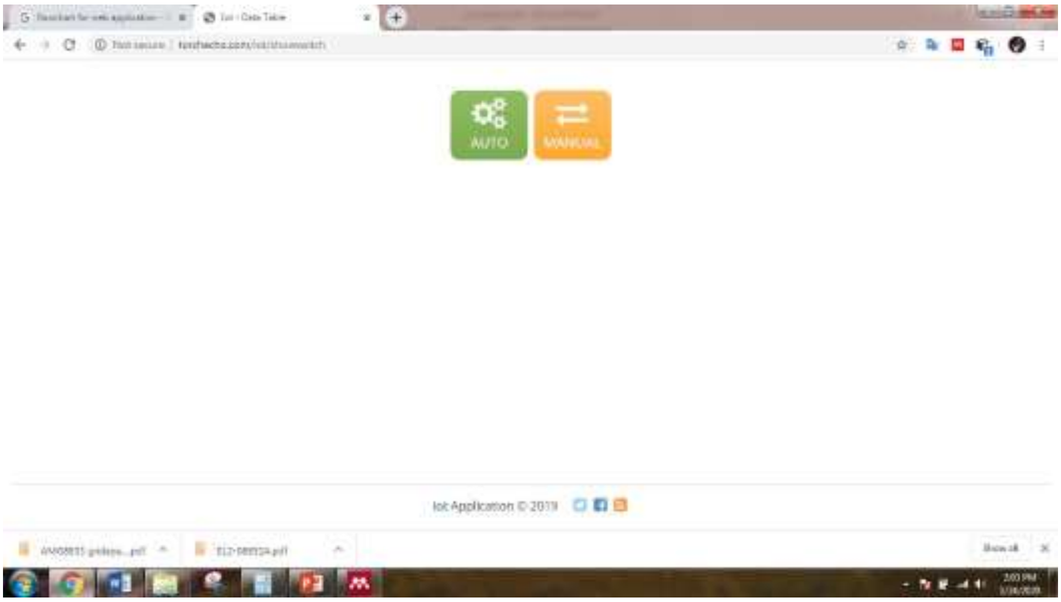


Plate XX: Web Application Button to Switch between Manual and Auto Mode

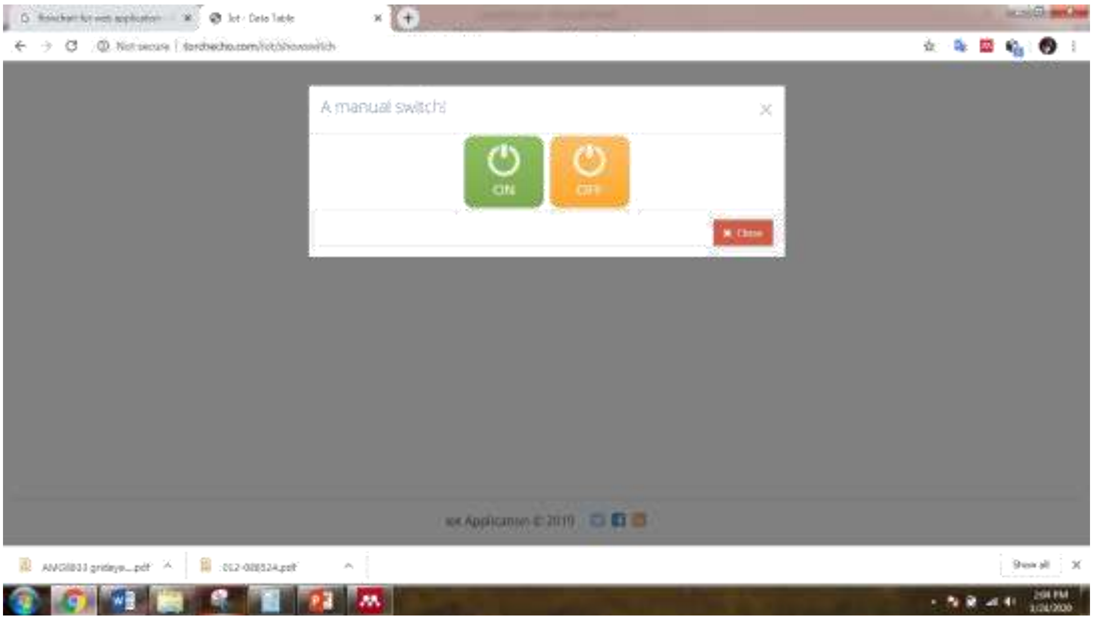


Plate XXI: Web Application Switch to On and Off

Figure 4.3 to 4.5 shows the plots of current against time, voltage against time and power against time respectively. The graphs was plotted directly on the web application that was developed, so that users can access their power consumption data graphically. It was observe that current graph and the power graph shows the period at which the load is activated and when it’s deactivated. The current and power graph also shows the inductive spike which occur during the switching of the load since the AC that was used for testing is an inductive load.

Figure 4.3: Plot of Current against Time

Figure 4.4: Plot of Voltage against Time

Figure 4.5: Plot of Power against Time

4.5 Discussion of Result

The human detection sensor was found to be working as expected but some challenges were encountered while trying to install it before it was finally decided to package it as bulb. According to the data sheet, the sensor can measure the temperature of an object accurately when it’s as close as possible to the module, but in the case of this project it was challenging to determine a particular threshold for the temperature to know when human is in the room and when human is not in the room because the temperature reading varies as the distance and become less accurate when the distance become more than 4 meters. It was later discovered in literatures that calculating the variance of the 64 temperature data sent by the sensor gave a useful threshold that was used and it finally worked as expected. Meanwhile another challenge of room temperature set in after installing the device in the office, because the variance method too start to fluctuate when the office temperature dropped below 27 degrees.

The energy measurement and control system also worked as expected and Figure 4.6 shows the graph from the data generated by the device when connected to a load.

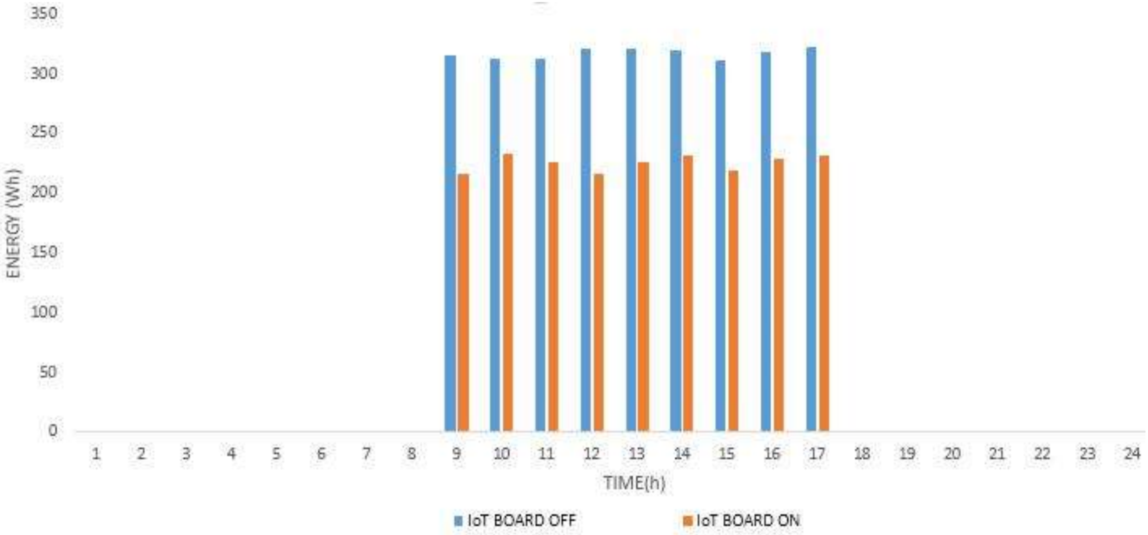


Figure 4.6: Graph of Energy Consumption with and without the IoT Device

The device was tested for working hour of the day 8.00am to 4.00pm, the energy consumption when the IoT device was off was found to be higher than the energy when the IoT device was used for control. The result gotten when the system was set up indicate that 38% energy was saved. This result shows improvement when compare with the result that was presented in Sindhuja & Balamurugan (2015) The energy saved was due to the ability for the human detection IoT device together with the bidirectional counter IoT device to detect when human being are no longer in the room which eventually shut down the load.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This section present the conclusions of this work based on the objectives. A cloud based system for energy management in buildings was designed, developed and was tested. The system was tested in a real life scenario.

5.1.1 Objective 1:

The power monitoring and control IoT device was tested in real life while it was connected to an air conditioner in the SEET Dean office. The system was tested and it worked well, the system communicated with the cloud through www.futminnaiot.tk. The data sent to the cloud was used to plot graph so that user can always see their power consumption on the go.

5.1.2 Objective 2:

The human detection IoT device was tested in real life while it was connected to a lamp holder in the SEET Dean office. The system was tested and it worked well, except for the difficulty in detecting whether or not, human is in the office when the office temperature goes below 26 degree, the system communicated with the cloud through www.futminnaiot.tk. The data sent to the cloud was used to plot a heat map graph so that user can always see at any point in time.

5.1.3 Objective 3:

The web was developed using HTML and CSS (front end) and PHP (back end) and communicate through HTTP protocol. It was observed that the project can actually solve one of the major problems in our society, which is the user's negligence to switch off appliances that are not needed, which often results in energy wastage. This was achieved via the use of the Auto mode of operation which power down the relay switch in this case an air conditioner, any time the office is found with no human being inside. The device was also able to save the power consumption of the load over time, which can be of importance for users in other to checkmate the actual usage with the monthly bill given by the utility company. It was also concluded that the contactless method of sensing electric current is easier to install and maintain than the conventional series resistance method and the current transformer method which was used in many literatures.

Furthermore the data generated on the server by the power monitoring and control IoT device can be used for further analysis by the utility companies when computed over long time and also help them in decision making in the nearest future. This can help improve the management of the little power generated in Nigeria efficiently. In conclusion the objectives of the project work was achieved to the best of our knowledge which make IoT a very good technology for solving power problem in the country.

5.2 Recommendations

To improve on the developed system the following recommendation were highlighted;

1. Double sided PCB board can be used so as to allow the use surface mounted device (SMD) component, which will reduce the size of the IoT boards.
2. The project was limited to just one user and one appliance, but the server can handle many users, it's recommended that more of the IoT boards can be produced and gather data from many users which will help in the data analysis.
3. Instead of using an existing Wi-Fi modem, a high speed gateway can be developed so as to reduce the latency in sending data to the cloud.

4. The packaging of the project can also be improved with the use of a 3D printer for a customized shape.
5. MQTT or COAP protocol can also be employed as this will reduce the latency and also reduce the cost of data for the communication between the IoT nodes and the cloud

5.3 Contribution to Knowledge

This work has contributed to knowledge by implementing a contactless magnetic current sensor which is easier to install than the conventional series resistance method and current transformer method. It has also created an automated database for online monitoring of electricity consumption. It also gives a user the ability to control automatically and manually, in addition the human detection sensor device make use of IR arrays sensor to monitor the heat signature emitted by every object in the room, so as to know when a human being is not in the room, the sensor used does not emit any IR ray for human safety in the room.

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APPENDIX A

Source code for Human detection board

```
/*
 * Human_Detection_Board.cpp
  * Created: 3/28/2021 11:43:36 AM
 *  Author: EngrBola
 */
#define F_CPU 11059200UL
#define F_i2c 100000UL
#define sbufSize  200
#define scl                         5
#define sda                         4
char serial_buff[sbufSize];
int cant = 0;       char buff[10];
//--------------------------------------------------------------------------------
#define ledPort             PORTD
#define ledDDR              DDRD
#define blu                         2
#define yel                         3
//====================================================
#include <MyAVR/BitStuff.h>
#include <MyAVR/lcdIIC.h>
#include <MyAVR/serial328.h>
#include <MyAVR/ESP8266.h>
#include <MyAVR/AMG88xx.h>

//========================================================
const char ssid[] = "Airtel 4G MiFi_1E83"; const char pword[] = "02882001";

const char ServerPort[]  = "80";
const char ServerHost[]  = " www.futminnaiot.tk";
//========================================================
ISR(USART_RX_vect)
{
        serial_buff[cant] = UDR0;
        cant++;
        if (cant > sbufSize)
        {
                cant = sbufSize/2;
        }
}
void blink(uint8_t led, uint8_t times)
{
        setBit(ledDDR, led);
        for (uint8_t a=0; a<times; a++)
        {
                setBit(ledPort, led);
                _delay_ms(200);
                clrBit(ledPort, led);
                _delay_ms(200);
        }
}
void print32(uint16_t a)
{
        lcdIIC_rub();
        for(uint16_t i=a; i<a+16; i++)
        {
                lcdIIC_data(serial_buff[i]);
        }
        lcdIIC_line2();
        for(uint16_t i=a+16; i<a+32; i++)
```

```
    {
        lcdIIC_data(serial_buff[i]);
    }
    _delay_ms(5000);
}
void showInfo(uint8_t pages)
{
    for (uint8_t x=0; x<pages; x++)
    {
        print32(x*32);
    }
}
void pushTemp(void)
{
    for (uint8_t a=0; a<64; a++)
    {
        dtostrf(temps[a], 5, 2, buff);
        serial_tx('/');
        for (uint8_t b=0; b<5; b++)
        {
            serial_tx(buff[b]);
        }
    }
}
void espSend(void)
{
    if (ESPsendATcmdRes("\r\n", 6, 5000, ">"))
    {
        clr_sbuff(sbufSize);
        serial_tx_string(getCMD1);
        pushTemp();
        serial_tx_string(getCMD2);
        while(cant < 100)
        {
            _delay_ms(500);
        }
        for (uint8_t a=0; a<sbufSize; a++)
        {
            if (serial_buff[a]=='A' && serial_buff[a+1]=='c' && serial_buff[a+2]=='k' &&
serial_buff[a+3]=='O' && serial_buff[a+4]=='k')
            {
                ESPsendATcmdRes("AT+CIPCLOSE\r\n", 13, 5000, "OK");
                serial_buff[0] = 0;
                break;
            }
        }
    }
}
void reconnect(void)
{
    uint8_t canta = 0;
    a1:
    clrBit(ledPort, blu);
    if (ESPconnect2server(ServerHost, ServerPort) == false)
    {
        blink(blu, 1);
        canta++;
        if (canta > 10)
        {
            goto a2;
        }
```

```
                goto a1;
        }
        else
        {
                //setBit(ledPort, blu);
                return;
        }
        a2:
        connect();
}
void minDelay(uint16_t min)
{
        for (uint16_t a=0; a<min; a++)
        {
                _delay_ms(30000);
                _delay_ms(30000);
        }
}
//=================================================================
int main(void)
{
  setBit(ledDDR, yel);
        setBit(ledDDR, blu);
        serial_init_inter(5);
  AMGinit();
        //lcdIIC_init();
        //lcdIIC_string("IoT Board Ready.");
        connect();
        AMGreadValues();
        espSend();
        if (serial_buff[0] == 0)
        {
                blink(blu, 3);
```

APPENDIX B

Source code for Power monitoring and control board

```
/*
 * power_monitor.cpp
  * Created: 3/30/2021 1:26:13 PM
 *  Author: EngrBola
 */
#define F_CPU 11059200UL
#define F_i2c 100000UL
#define sbufSize  200
#define scl                         5
#define sda                         4
char serial_buff[sbufSize];
int cant = 0;       char buff[10];
 //----------------------------------------------------------------------------------------------------
#define ledPort             PORTD
#define ledDDR              DDRD
#define blu                         2
#define yel                         3
#define relay               1
//======================================================================
#include <MyAVR/BitStuff.h>
#include <MyAVR/lcdIIC.h>
#include <MyAVR/serial328.h>
#include <MyAVR/ESP8266.h>
//======================================================================
const char ssid[]  = "Airtel 4G MiFi_1E83";
const char pword[]  = "02882001";
const char ServerPort[]  = "80";
const char ServerHost[]  = "www.futminnaiot.tk";
float curent = 0.0; uint8_t curLen = 0; char curArray[10];
//=====================================================================
ISR(USART_RX_vect)
{
        serial_buff[cant] = UDR0;
        cant++;
        if (cant > sbufSize)
        {
                cant = sbufSize/2;
        }
}
void blink(uint8_t led, uint8_t times)
{
        setBit(ledDDR, led);
        for (uint8_t a=0; a<times; a++)
        {
                setBit(ledPort, led);
                _delay_ms(200);
                clrBit(ledPort, led);
                _delay_ms(200);
        }
}
void print32(uint16_t a)
{
        lcdIIC_rub();
        for(uint16_t i=a; i<a+16; i++)
        {
                lcdIIC_data(serial_buff[i]);
        }
        lcdIIC_line2();
```

```
		for(uint16_t i=a+16; i<a+32; i++)
		{
			lcdIIC_data(serial_buff[i]);
		}
		_delay_ms(5000);
}
void showInfo(uint8_t pages)
{
		for (uint8_t x=0; x<pages; x++)
		{
			print32(x*32);
		}
}
void pushCurrent(void)
{
		if (curArray[0] == ' ')
		{curArray[0] = '0'; }

		for (uint8_t b=0; b<curLen; b++)
		{
			serial_tx(buff[b]);
		}
}
void getCurrent(void)
{
		for (uint8_t i=0; i<50; i++)
		{
			readValue = adc_read(0);

			_delay_ms(1);
		}
		int valu = maxValue - minValue;
		if (valu <= 3)
		{
			valu = 0;
		}
		curent = valu * 0.011;
		dtostrf(curent, 7, 4, curArray);
		curLen = (uint8_t)strlen(curArray);
}
void espSend(void)
{
		uint16_t getLen = ((uint8_t)strlen(getCMD1)) + ((uint8_t)strlen(getCMD2)) +
		curLen; //------------------------------------------------------------------------------
		clr_sbuff(50);
		serial_tx_string("AT+CIPSEND=");

		if (ESPsendATcmdRes("\r\n", 6, 5000, ">"))
		{
			clr_sbuff(sbufSize);
			serial_tx_string(getCMD1);
			pushCurrent();
			serial_tx_string(getCMD2);
			while(cant < 100)
			{
				_delay_ms(500);
			}
			for (uint8_t a=0; a<sbufSize; a++)
			{
				if (serial_buff[a]=='A' && serial_buff[a+1]=='c' && serial_buff[a+2]=='k' &&
serial_buff[a+3]=='O' && serial_buff[a+4]=='k')
```

```
                        {
                                if (serial_buff[a+5] == '0')
                                {       clrBit(PORTB, relay);   }
                                else
                                {       setBit(PORTB, relay);   }

                                ESPsendATcmdRes("AT+CIPCLOSE\r\n", 13, 5000, "OK");
                                serial_buff[0] = 0;
                                break;
                        }
                }
        }
}
void reconnect(void)
{
        uint8_t canta = 0;
        a1:
        clrBit(ledPort, blu);
        if (ESPconnect2server(ServerHost, ServerPort) == false)
        {
                blink(blu, 1);
                canta++;
                if (canta > 10)
                {
                        goto a2;
                }
                goto a1;
        }
        else
        {
                //setBit(ledPort, blu);
                return;
        }
        a2:
        connect();
//==================================================================
int main(void)
{
  setBit(DDRB, relay);
        setBit(ledDDR, yel);
        setBit(ledDDR, blu);
        serial_init_inter(5);
  getCurrent();
        //lcdIIC_init();
        //lcdIIC_string("IoT Board Ready.");
        connect();
        espSend();
        while(1)
  {
    getCurrent();
                reconnect();
                espSend();
                if (serial_buff[0] == 0)
                {
                        blink(blu, 3);
                }
                else
                {
                        blink(yel, 3);
                }
                _delay_ms(15000);
```

APPENDIX C

Source code for the Bidirectional Counter IoT Board

```
/*
 * Sample_Node.cpp
*
 * Created: 10/10/2020 1:32:37 PM
 *  Author: EngrBola
 */

#define F_CPU 11059200UL
#define F_i2c 100000UL
#define sbufSize  288
#define scl                             5
#define sda                             4
char serial_buff[sbufSize];
int cant = 0;         //char buff[10];
char flag1, flag0;
//-----------------------------------------------------------
const char ssid[]     = "Airtel 4G MiFi_1E83";
const char pword[]  = "02882001";
const char ServerPort[]     = "80";
const char ServerHost[]  = "www.futminnaiot.tk";
//-----------------------------------------------------------
#define ledPort                 PORTD
#define ledDDR                  DDRD
#define ledPin                  4
//-----------------------------------------------------------
int calc[32];
char bufa[10];
char lBuf[40];
int people = 0;
int tresh = 200;
//-----------------------------------------------------------
ISR(USART_RX_vect)
{
        serial_buff[cant] = UDR0;
        cant++;
        if (cant > sbufSize)
        {
                cant = sbufSize/2;
        }
}
void blink(uint8_t times)
{
        for (uint8_t a=0; a<times; a++)
        {
                setBit(ledPort, ledPin);
                _delay_ms(200);
                clrBit(ledPort, ledPin);
                _delay_ms(100);
        }
}
int adc_sample(unsigned char channel, unsigned char sample)
{
        unsigned int ave = 0;
        for (int a=0; a<sample; a++)
        {
                calc[a] = adc_read(channel);
                ave += calc[a];
                _delay_ms(1);
        }
```

```
	ave = ave / sample;
	return ave;
}
void print32(uint16_t a)
{
	lcdIIC_rub();
	for(uint16_t i=a; i<a+16; i++)
	{
		lcdIIC_data(serial_buff[i]);
	}
	lcdIIC_line2();
	for(uint16_t i=a+16; i<a+32; i++)
	{
		lcdIIC_data(serial_buff[i]);
	}
	_delay_ms(5000);
}
void showInfo(uint8_t pages)
{
	for (uint8_t x=0; x<pages; x++)
	{
		print32(x*32);
	}
}
void reconnect(void)
{
	uint8_t canta = 0;
	a1:
	clrBit(ledPort, ledPin);
	if (ESPconnect2server(ServerHost, ServerPort) == false)
	{
		canta++;
		if (canta > 3)
		{
			goto a2;
		}
		goto a1;
	}
	else
	{
		blink(1);
		return;
	}
	a2:
	connect();
}
void showPeople(void)
{
	lcdIIC_rub();
	ltoa(people, bufa, 10);
	lcdIIC_string(bufa);
}
void espSend(uint8_t inData)
{
	char getCMD1[] = "GET /iot/data3/001/";
	uint16_t getLen = ((uint8_t)strlen(getCMD1)) + ((uint8_t)strlen(getCMD2)) +
	1; //-------------------------------------------------------------------------------
	clr_sbuff(50);
	serial_tx_string("AT+CIPSEND=");
	if (ESPsendATcmdRes("\r\n", 6, 5000, ">"))
	{
```

```
		clr_sbuff(sbufSize);
		serial_tx_string(getCMD1);
		serial_tx(inData);
		serial_tx_string(getCMD2);
		while(cant < 50)
		{
			_delay_ms(200);
		}
		//showInfo(9);
		//while(1);
		for (uint16_t a=0; a<sbufSize; a++)
		{
			if (serial_buff[a]=='A' && serial_buff[a+1]=='c' && serial_buff[a+2]=='k' &&
serial_buff[a+3]=='O' && serial_buff[a+4]=='k')
			{
				ESPsendATcmdRes("AT+CIPCLOSE\r\n", 13, 5000, "OK");
				blink(2);
				break;
			}
		}
	}
}
//-------------------------------------------------------
int main(void)
{
	setBit(ledDDR, ledPin);
	lcdIIC_init();
	lcdIIC_string("Ready...");
	_delay_ms(1000);
	serial_init_inter(5);
	connect();
	espSend('0');
	int ldr0 = adc_read(0);
	int ldr1 = adc_read(1);
	//===================================================
	while(1)
	{
		ldr0 = adc_read(0);
		ldr1 = adc_read(1);
		//_delay_ms(500);
		if ((ldr0 > tresh) || (ldr1 > tresh))
		{
			if (ldr0 > tresh)
			{
				while(adc_read(1) < tresh);

				people+=1;
				showPeople();
				if (people == 1)
				{
					reconnect();
					espSend('1');
				}
				while((adc_read(0) > tresh) || (adc_read(1) > tresh));
```