UNIVERSITY OF DAR ES SALAAM

COLLEGE OF ENGINEERING AND TECHNOLOGY.

DEPARTMENT OF ELECTRICAL ENGINEERING (EE).

EE498: FINAL YEAR PROJECT I (FINAL REPORT)

DESIGN AND IMPLEMENTATION OF SYSTEM FOR ENERGY MONITORING AND CONTROL FOR MULTI-TENANT BUILDING

A Project Report in Partial Fulfilment for the Award of Bachelor of Science in Electrical Engineering

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Supervisor's Signature: **…………………………….**

Submission Date : **11th July,2022**

DECLARATION

I ANG`WEGILE, LUKELO BOAZ a student of Bachelor of Science in electrical engineering, declares that this project report “Design and implementation of a contactless digital tachometer”. Submitted to the University of Dar es salaam in Partial Fulfilment for the Award of Bachelor of science in Electrical Engineering is based on my own work under the guidance of Dr. Santos Kihwele. I further declare that, information from other sources like books, articles and journals included in this report I credited them and given their details in the references.

Student name: Ang’wegile , Lukelo Boaz

Signature: …………….

Date 11/07/2022

This report may proceed for submission for assessment for the Award of Bachelor of science in Electrical Engineering at the University of Dar es salaam.

Supervisor Signature: ………………………

Date: ……………………….

ABSTRACT

Now days in urban areas also in rural area with development there is a lot of building with more than one tenant. In this building in some case, it is happened is difficult for each tenant to have his/her own electrical infrastructure, so they have to share the some of electrical infrastructure like distribution board and utility meter to reduce cost of installation of electrical system.

In this system of multi-tenant building sharing there is problem of electrical bill calculation and also abnormal electrical usage which can lead fire like when someone accidentally left submerged water heater on and go away from house so when water heated it will   evaporate and when all water evaporate it will lead fire.

So, objective of projective is to design system that will help to monitor electrical energy use data collected from monitoring to **predict energy usage** and also detect abnormal electrical usage and protect tenants by disconnect tenant with abnormal usage. Also, Landlord will have power to **disconnect any tenant from main power** when he/she need to do so.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the almighty GOD for his gift of life, good health, love, protection, knowledge, wisdom and guidance which have been the spearheads towards accomplishment of this project.

I would also like to thank my project supervisor Dr. Santos Kihwele for his support, supervision, good advice, encouragement and challenges that helped me to accomplish my project, may the almighty GOD bless him.

I would like to extend my gratitude to the electrical engineering department project coordinator Mr. Shaban O Kasinge for his support during my project work.

Moreover, I would like to thank the staff members from the department of electrical engineering in College of Engineering and Technology (CoET) at the University of Dar es salaam who taught me and helped to acquire the fundamental knowledge and skills during the class periods which served the initial capital of knowledge for my project work.

Last but not least, I would like to thank my family, friends and the fellow Electrical Engineering students 2021/2022 for their help and cooperation towards completion of my project.

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LIST OF ABBREVIATIONS

IDE-Integrated Development Environment

GSM-Global System for Mobile communication

GPRS-.GlobalRadio PacketService

LED-Light Emitting Diode

SMS-Short Message Service

USB-Universal Bus Interface

CHAPTER ONE

GENERAL INTRODUCTION

1.1: INTRODUCTION

Electrical energy usage is very dynamic between users. It is necessary to measure and monitor energy for each user in multi-tenant building. Monitoring can help in bill calculation and prediction, beside bill calculation and prediction it important to have control on flow of energy to each tenant so as to have ability to disconnect any user from mains supply when needed.

1.2: PROBLEM STATEMENT

This project will try to resolve the following problem which tenants and landlord are facing in multi-tenant building: -

First is difficulties in electrical bill calculation for each tenant in multi-tenant building using single utility meter

Second is presence of tenant who in some case fail to pay the bill and have to be temporary disconnected from mains power

1.3: MAIN OBJECTIVES

To design and implement energy monitoring and control system

1.4: SPECIFIC OBJECTIVES

The following are specific objective to be achieved in this project: -

- To design voltage and current measuring devices
- To design energy calculation and control system
- To design users interface system
- To implement the proposed system

1.5: REASEARCH QUESTIONS

The following are research question which this project will try to answer: -

- What are methods used to measure voltage and current?
- What are systems used to measure and control energy?
- How user / tenant interface with energy monitoring and control system?

1.6: SIGNIFICANCE OF PROJECT

The following are significance of project which make it more fisible to society :-

- Reduce conflict between tenant on electrical bills
- Give landlord more control on electrical energy
- Protect tenant from electrical fire caused by abnormal electrical usage

CHAPTER TWO: LITERATURE REVIEW

2.1: OVERVIEW

In this project will involve energy monitoring and control in building with more than one tenant .In monitoring will involve ability for proposed system to interface with exist system.

2.2: EXISTING SYSTEM

In nowdays in multi-tenant building there three ways of monitoring energy usage which are :-

- Using sub metering
- Using separate utility meters
- Using load estimation (human estimation)

The most common method used to monitoring is sub metering method where each tenant have his own energy meter measuring his usage the manual calculation are required to get bill .

In separate utility meter there is no need to calculate electrical bill as each tenant pay his own bill based on his usage .This method is good but have expensive initial cost that's why most people don't use unless cost using sub metering is high than use separate utility meters .Also this type of energy monitoring require each tenant to have his own separate wiring system which increase cost of installation.

In load estimation method electrical bill is calculated based how much load tenant have. In this case Landlord have power to demand bill for electricity based on his own estimation sometimes are not fair.

Figure 2example of sub metering in house

Figure 1 separate utility metering in house

2.1.6. Difference between smart meter and energy monitoring system

An energy monitor is a simple device that you can fit yourself, it works with an existing electricity meter to give you an indication of your electricity use. Energy monitors cannot communicate with your energy supplier and do not directly affect your bill.

Smart meters, on the other hand, are new meters that will replace existing electricity meters and provide a communication channel between your home and your energy supplier. This means your energy supplier will have the ability to read your meter remotely and use this information to bill you for your actual energy use. (npower, 2020)

2.3: PROPOSED SOLUTION

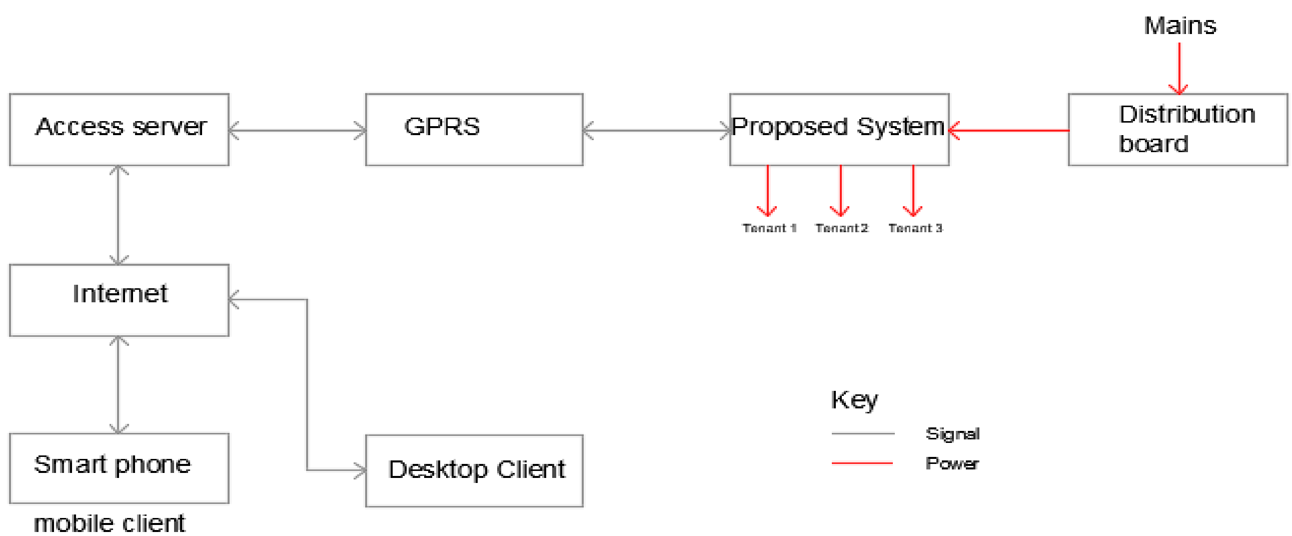


Figure 3 block diagram of proposed solution

2.4: COMPONENTS OF A PROPOSED SOLUTION

2.4.1: MICROCONTROLLER

Based on the function of the microcontroller (Arduino) the program was logically coded in the Arduino IDE software and checked for the errors. If there is any error it will be displayed in the message box. After removing the errors, the sketch can be compiled and run successfully. Finally, the sketch is uploaded into the Arduino controller through USB serial interface.

2.4.2 VOLTAGE AND CURRENT MEASURING DEVICES

Will be part main that will monitor energy by measuring voltage and current and then software in Arduino will calculate energy and hence be able know different parameters like power factor, maximum demand and other thing.

2.4.3 GSM/GPRS MODULE

The GSM/GPRSmodule is interfaced with Arduino controller through Serial communication (UART) via AT commands. GPRS service enable transfer of data through internet to access server

2.4.3 ACCESS SERVER

This main server of proposed system in which user may be able access and interface with the system to obtained their bill predicted or calculated. Also, land lord will be able to control energy via prosed system to disconnect any tenant from mains when needed

2.4: WORK ALREADY DONE

- Weekly consultation to the project supervisor.
- Regular literature reviewing on topics
- Configuring the access server
- Design of proposed system
- Construction of the project prototype
- Testing of the project prototype
- Report writing

CHAPTER THREE: PROPOSED SYSTEM

3.1 PROPOSED SYSTEM

The figure below shows the block diagram of the overall proposed energy monitoring system.

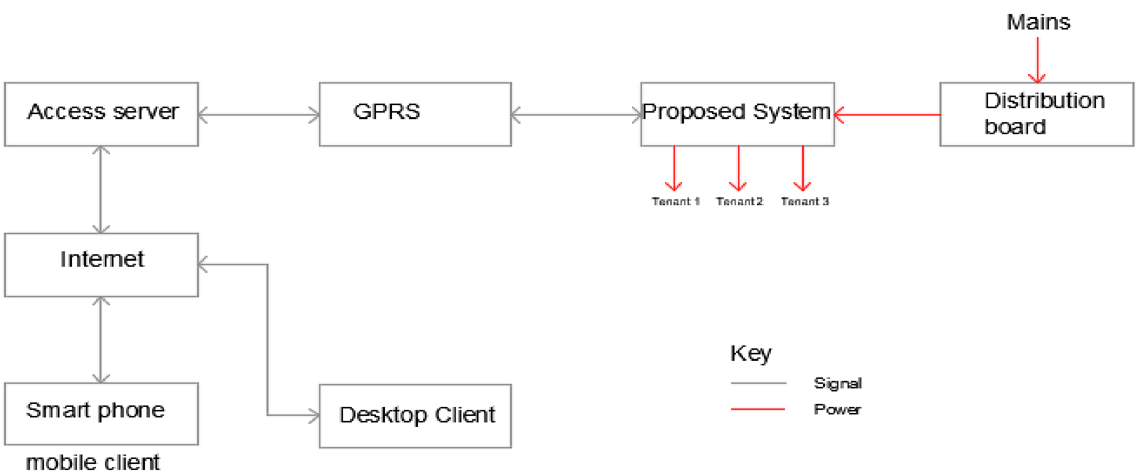


Figure 3: Proposed energy monitoring system.

The figure below shows the block diagram of the proposed energy monitoring circuit using a microcontroller.

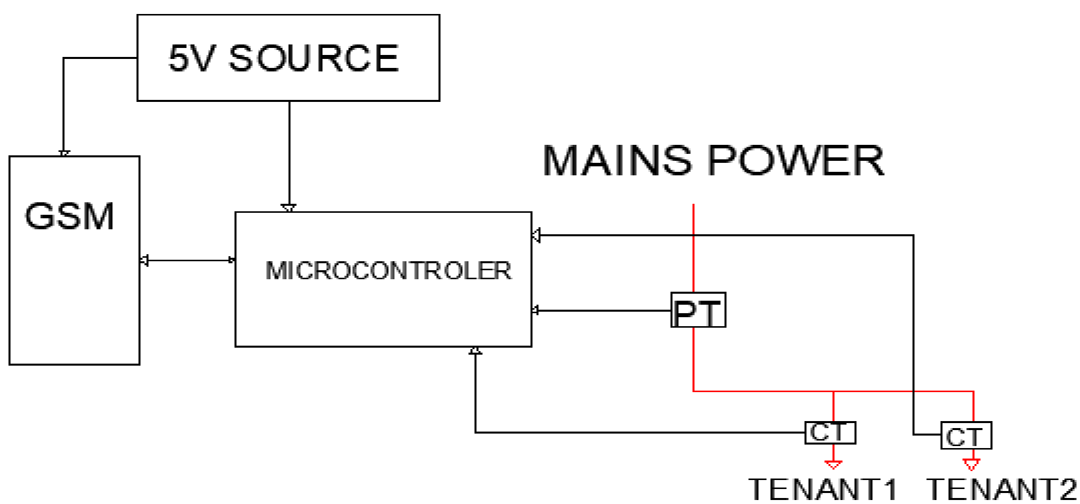


Figure 4 Proposed energy monitoring main circuit.

3.2 MAIN COMPONENTS OF THE PROPOSED SYSTEM

3.2.1. Microcontroller

The microcontroller is a small computer consists of the microprocessor (CPU), memory, and programmable input/output peripherals in a single chip. For this system. Arduino UNO will be used as the main microcontroller since its development board with easy programming capabilities, which will be programmed to provide the interface between inputs which are voltage and current sensors, and send data to the server via GSM module by GPRS.

3.2.2. Voltage sensor

A voltage sensor will be used to measure voltage values from the AC power supply and send the value to the microcontroller. for this project 250 AC voltage sensor will be used since it consists of a Potential transformer (PT) which will take the voltage range up to 250V and transform it to voltage range p to 5V which can be handled with the microcontroller.

3.2.3. Current sensor

The current sensor will be used to measure current values from the AC power supply and send the value to the microcontroller. For this project, ACS712 Current Sensor Module will be used since it uses the principle of Hall-Effect to measure the high value of current, by this effect the high value of current is transformed to the small value of current which can be handled with a microcontroller.

3.2.5. DC Power supply circuit

DC power supply will be used to provide DC voltage to the Arduino and other devices such as sensors that require DC voltage.

3.3 HOW SYSTEM WORK

Cloud-based home energy monitoring systems consist of three main parts which are the main circuit, database, and web app. Below is the description of how these parts operating to meet the required goal.

3.3.1. Main Circuit

This is the circuit which composes of a microcontroller connected to the input and output device. The circuit contains a voltage sensor and current sensor which used for the detection and measurement of voltage and current respectively, these sensors are connected directly to the power supply and due to their capability, they transform those higher value to lower values that can be received without damaging the microcontroller. The microcontroller due to its capability of being programmed, the specially developed program will be used to calculate RMS values of voltage and current, and the average power and power factor from the input signal received from the sensors the data will be sent to server where clients will be able to access them via web app

3.3.2. Database

The database will be located at the server, it will be used to keep a record of the measure and calculated data, user and device information such as username, password, device number (or id). The importance of the cloud database is to provide the storage of data in the cloud that can be accessed anytime and any device that can be connected to the internet. For this project, the firebase real-time database will be used as the storage of the database and server for hosting the web app.

3.3.3. Web app

Web application (web app) is application software that runs on a web server, unlike computer-based software programs that are run locally on the operating system (OS) of the device. Web applications are accessed by the user through a web browser with an active network connection. (Wikipedia, 2022). Web app for this system will contain the user interface developed mainly to display important information such as energy consumption, amount of energy remained and cost for the energy used, real power, power factor, and real-time load curve to the user. This web app will fetch this data from the database and also send data to the database such as user inputs since a user will be able to fill the electric unit, he prepaid in the system to keep track of how much energy remain, also for the user login and out. Since it this web app runs on a web server it will be accessed by any device that has a web browser.

3.4 COMPONENTS SPECIFICATIONS

The following are the specification of components used in this system:

3.4.1. Arduino UNO

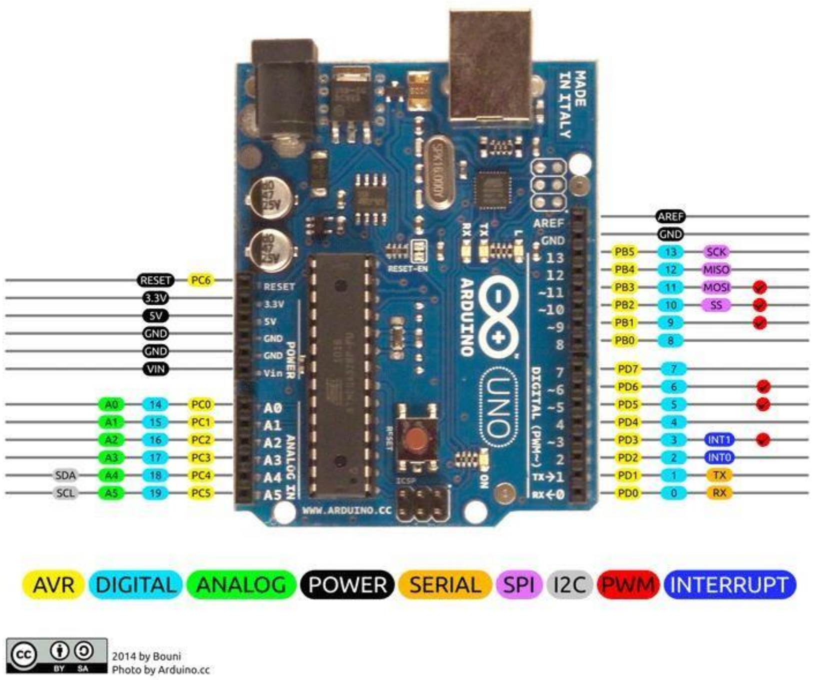


Figure 5: Arduino UNO pin layout (Components101, 2018)

Table 1: Arduino UNO specification

Microcontroller	ATmega328P –8bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)

Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

3.4.2. Current sensor – (ACS712 Current Sensor Module)

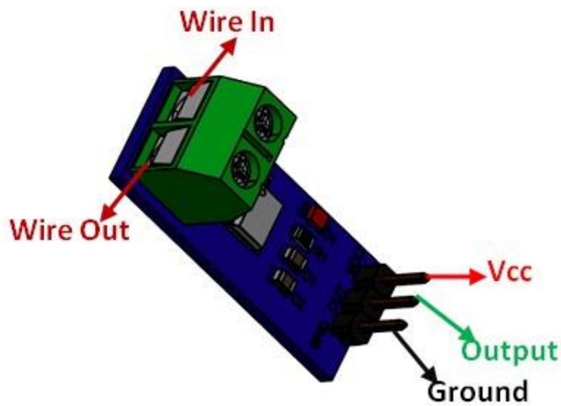


Figure 6: ACS712 Current Sensor Module (components101, 2018)

- Measures both AC and DC current
- Available as 5A, 20A, and 30A module
- Provides isolation from the load
- Easy to integrate with MCU, since it outputs the analogue voltage Scale Factor:

Table 2: ACS712 current sensor scale factor

5A Module	20A Module	30A Module
185mV/Amp	100mV/Amp	66mV per Amp

3.4.3. ZMPT101B 250V - AC voltage sensor

Figure 7: ZMPT101B AC voltage sensor – 250V (botshop, 2021)

AC voltage sensor – 250V Specifications

- Measure within 250V AC
- Onboard micro-precision voltage transformer
- Analog output corresponding quantity can be adjusted.
- Good consistency, for voltage and power measurement
- Very efficient and accuracy
- Output Signal: Analog 0 – 5V
- Size: 49.5 (mm) x19.4 (mm)
- Operating temperature: 40ºC ~ + 70ºC

3.5 SYSTEM SOFTWARE SPECIFICATION

The following software will be used in the system development

3.5.1. Arduino IDE

This is an Arduino integrated development environment (IDE) that will be used to write source code, debug and upload to the Arduino UNO microcontroller.

3.5.2. Firebase

Firebase Realtime Database is a cloud-hosted NoSQL database that lets you store and sync data between your users in real-time. This will be used to create and store a database, also will be used to host the web app.

3.5.3.Vue JS

Vue js is an application design framework and development platform for creating an efficient and sophisticated single-page app. Vue js is a TypeScript-based open-source web application framework. This will be used to create the user interface of the web app.

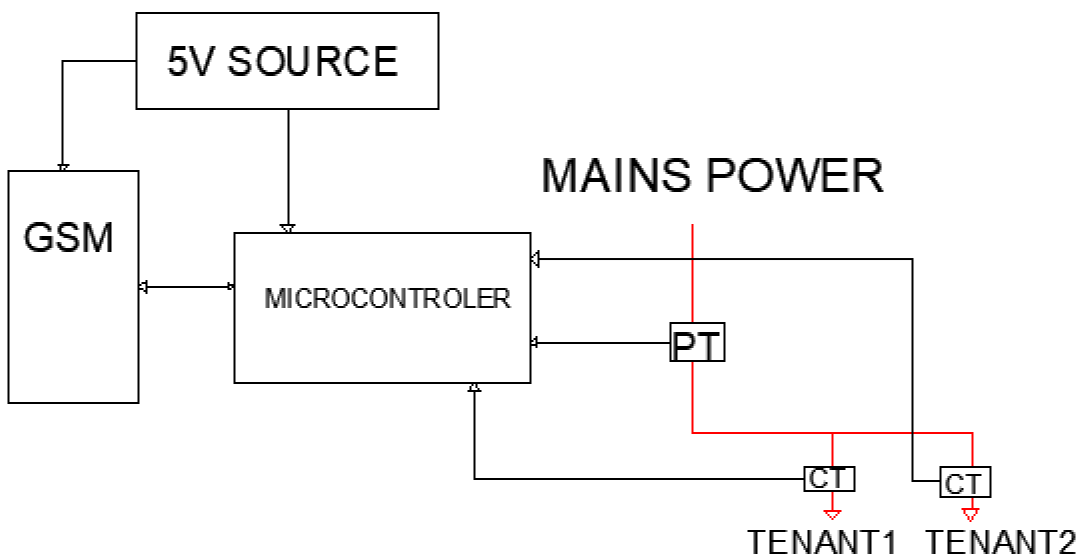
CHAPTER FOUR: DETAILED DESIGN

4.0. INTRODUCTION

This chapter deals with system circuit designing, database, and web app designing. which will involve circuit designing of different parts hardware programming that will later be integrated to makes up the entire system. The system design can be well grouped into five parts which are Measurement circuit design, Database design, and Interface design.

4.1. MEASUREMENT CIRCUIT DESIGN

Measuring circuit will involve current sensor to each tenant and one voltage sensor also to each tenant there will be relay connected in series for turn on and off power below is diagram of measuring circuit



4.2 The Root Mean Square Power Calculation

The RMS AC Power is also known as apparent power and is the product of RMS AC Voltage and RMS AC Current values. The RMS AC Voltage and RMS AC Current are calculated separately to obtain RMS AC Power.

The measuring circuit will be designed to calculate a value which is derived from averaging 1000 samples per set this each sample is recorded every 1 millisecond (0.001 seconds). In other words, the total complete set is equivalent to 50 waves with each wave is divided into 20 sections or readings (for 50Hz). Technically it should last 1 second for 1 set of reading.

Each single sample analog value is being squared initially and once the 1000 sample values are accumulated, the average value from the 1000 samples is then being square-rooted to come out the RMS analog value (for 1 sensor). Then Convert the RMS analog value into measured voltage or current value. Similar calculations will be done separately for the other sensor and multiply both RMS values to become RMS AC Power. The figure below is an example of how the code will work. take a quarter of the wave as an example.

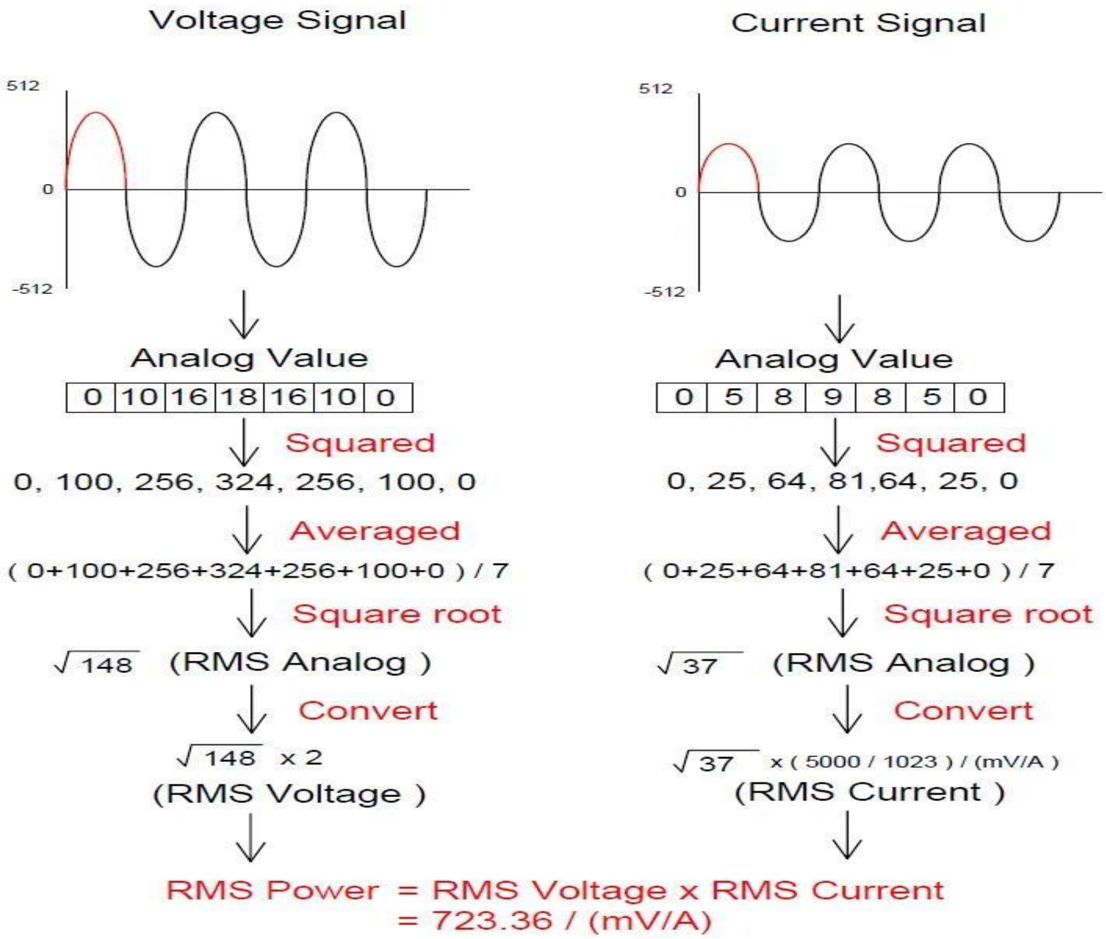


Figure 10: Calculation of RMS power (Solarduino, 2020)

4.3. The Instantaneous Power Calculation

For Active or Real Power, the measurement circuit will be designed to calculate the average value of all the multiplications of instantaneous voltage and instantaneous current value. Both voltage and current analog values are first converted into measured voltage and current values. The voltage is then multiplied by its instantaneous current value and becomes a sample reading. Similar to the RMS power method, the Active Power is also derived from averaging 1000 samples per set. Each sample is recorded every millisecond, in other words, the total complete set is equivalent to 50 waves with each wave is divided into 20 sections or readings (for 50Hz).

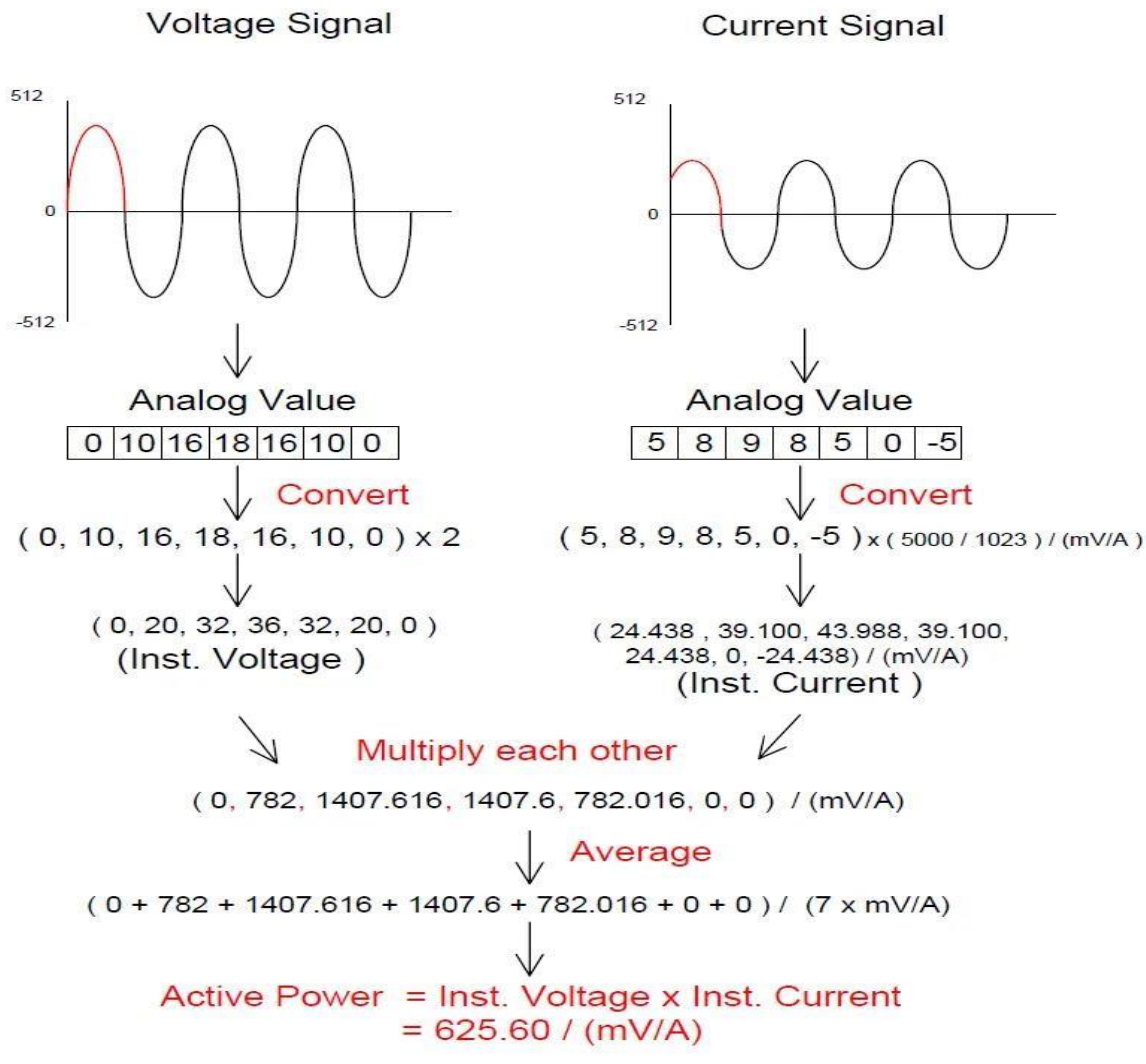


Figure 11: Active power calculation (Solarduino, 2020)

4.4 Sending Data to Server

Data will be sent via GSM to the server where it will be processed and stored to Database . Data will that will be sent to the server will include real-time power , voltage ,and current and powerfactor.

Data will be sent at interval of 5 seconds .thus at each minute there will be 12 data package sent server

CHAPTER FIVE: SIMULATION AND ANALYSIS

5.0. SIMULATION RESULTS

Simulation refers to the imitation of the operation of a real-world process or system over time. Simulations require the use of models; the model is created represents the key characteristics or behaviors of the selected physical system or process. Simulation helps to study the behavior of a system without building it, find un-expected phenomenon behavior of the system and perform "What-If" analysis. for this project, simulation was done through the PROTEUS DESIGN SUITE 8 Version 8.13.

Simulation consists of voltage sensor and current sensor as input of microcontroller and the virtual terminal.

LampA and inductor used to simulate the various type of load found in residential houses since most of home electrical appliances are resistive and inductive load. By switching different combination of these loads in the simulation gives to see the changes of current, power and power factor values in the system.

C++ language has been used to develop a basic operation such as detecting sensor values and calculation of current and voltage rms values, real and apparent power, and power factor.

The simulation also has three sections which are Metering section where load is measured, microcontroller (MCU) unit where calculation is performed and displays section for monitoring simulation results as shown in figure 15 below.

5.1. SCHEMATIC DIAGRAM

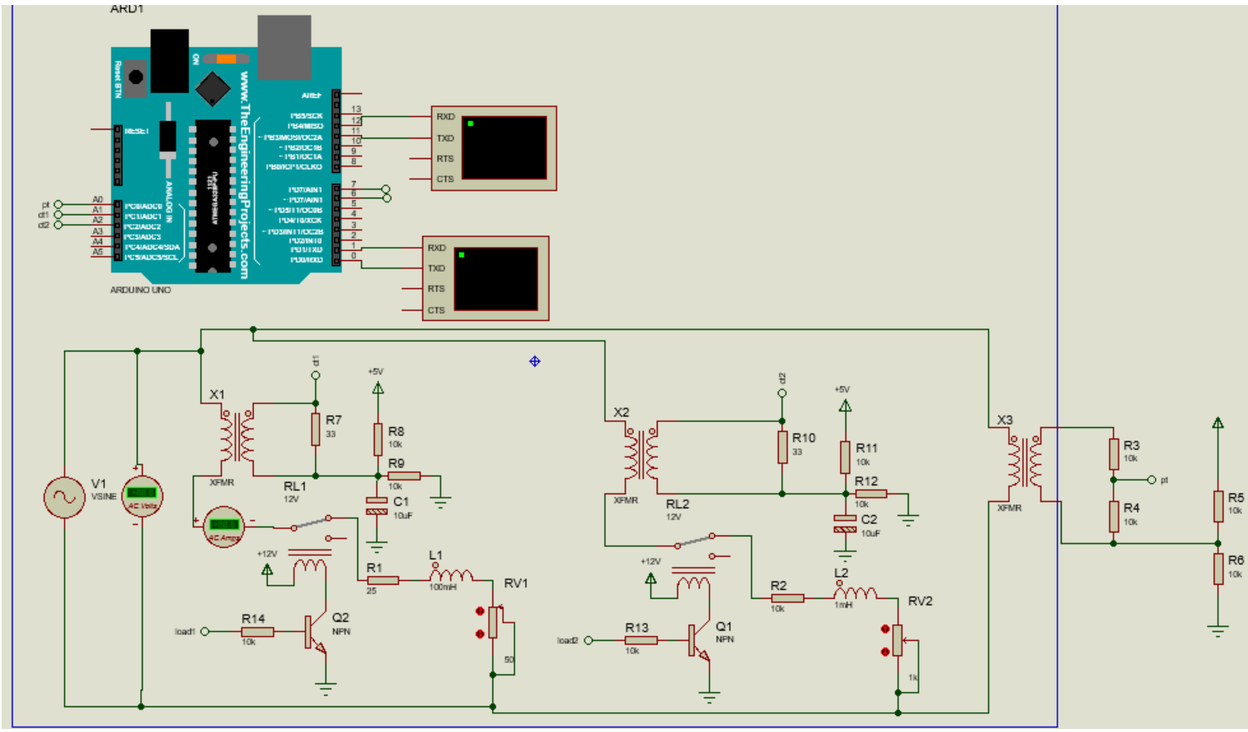


Figure 15: Simulation Schematic Diagram

5.1.2. Resistive load is switched on

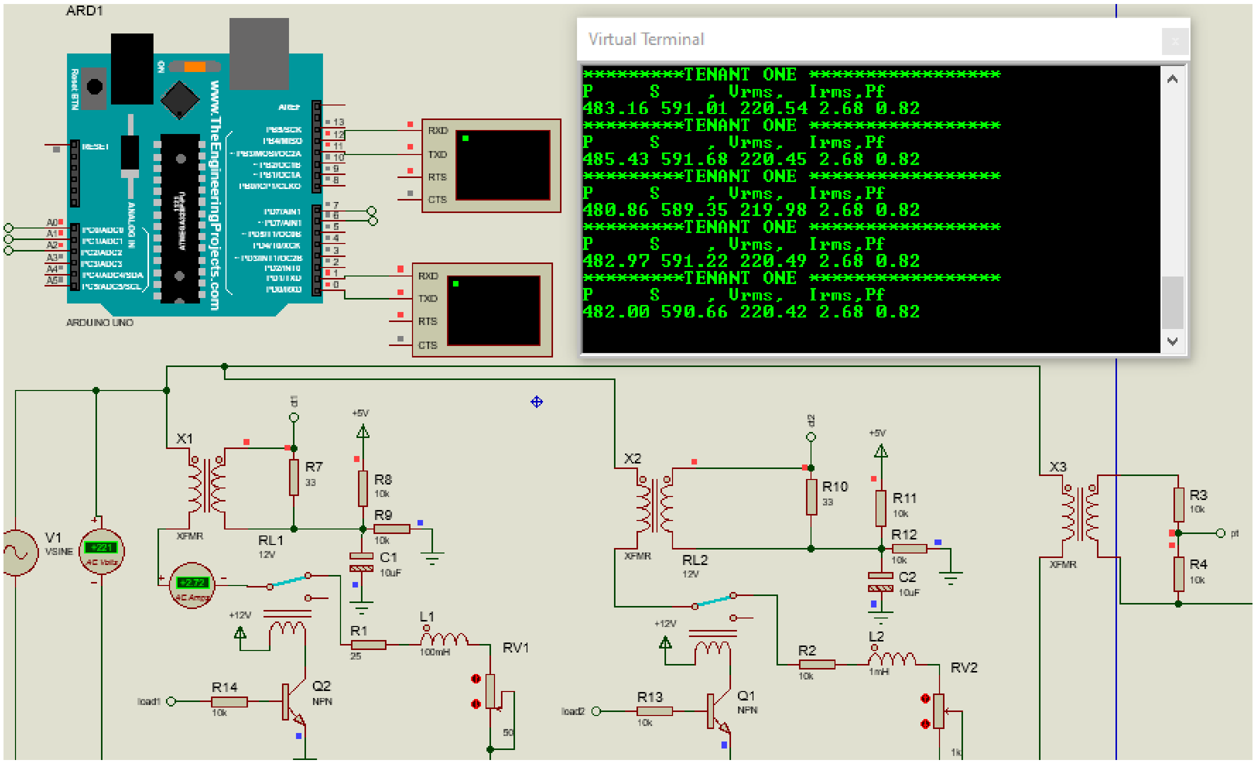


Figure 16: Simulation Result when resistive load switched on

5.1.3. Two Resistive-Inductive (RL) load are switched on

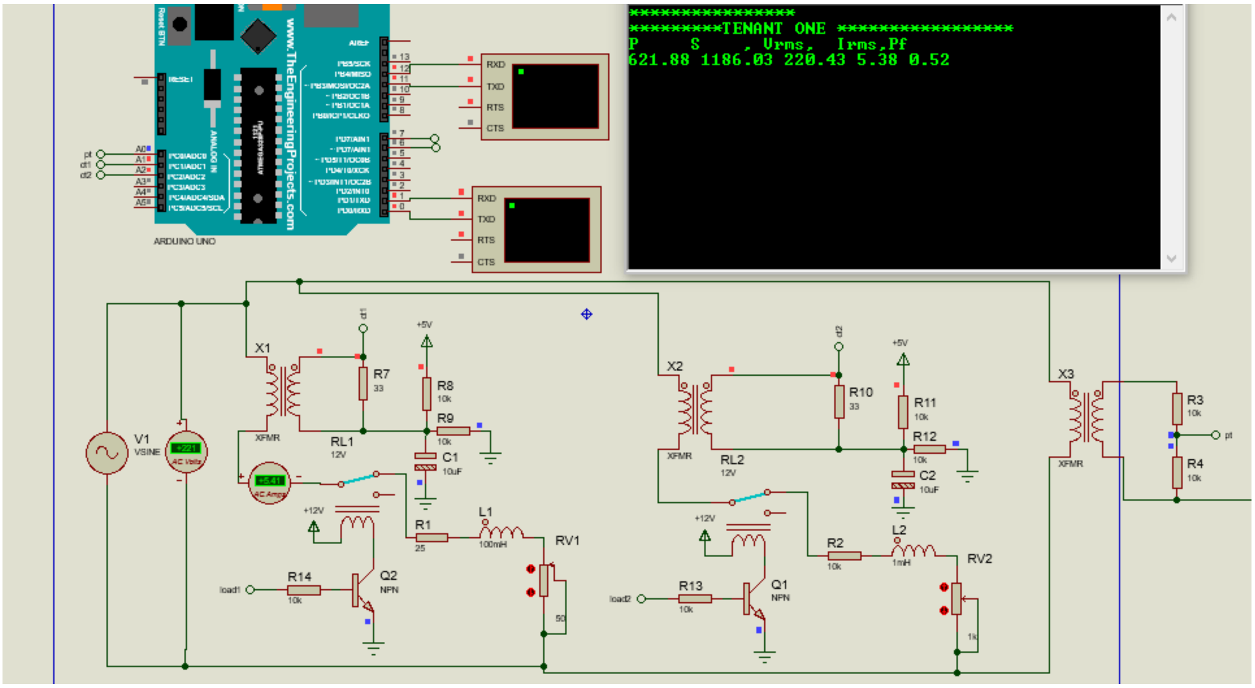


Figure 17: Simulation Result when two resistive-inductive RL loads switched on

CHAPTER SIX : PROTOTYPE IMPLEMENTATION AND TEST

6.0 Introduction

This chapter deals with the physical implementation of the proposed system solution so that it materializes and performs its required tasks sufficiently according to the design objectives. It involves both the software and hardware parts of the proposed system solution. The software is built first which consists of the writing and uploading a program code that contains the instructions about the microcontroller operations. The hardware part of the system is then built and this involves connecting the circuit components according to the design.

6.1Tools and equipments used

The following are the tools and equipments used in the implementation of the system.

6.1.1 Soldering gun and solder wire

Used for joining different system components to make a complete circuit. Figure 20 shows a soldering gun.

Figure 7: A soldering gun

6.1.2 Bread board and jumper wires

Used for making an initial temporary connection of the system circuit in order to check the system performance before building a permanent soldered circuit on a PCB. A bread board is shown in figure 21 below.

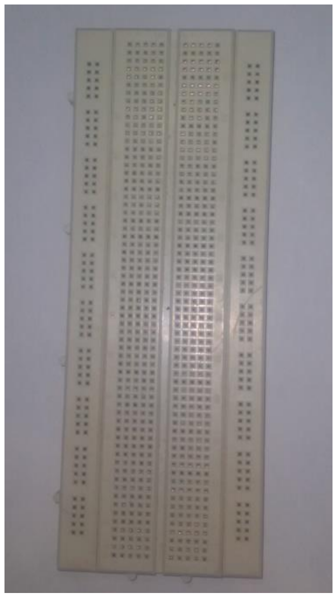


*Figure **8**: A bread board used for making temporary connections*

7.1.3 Digital multimeter.

A digital multimeter was used to measure different component parameters and test for circuit continuity during prototype building. A DT 9205A digital multimeter used for circuit inspection is shown in figure 10.

*Figure **10**: A DT 9205A digital multimeter*

6.2 Software

This is a program code containing important instructions that guide the system's operation. In this project, a program code for the operation of a contactless digital tachometer was written using C++ programming language. The code was compiled and run-on Arduino IDE software. After verification and debugging, the code was uploaded to the system's Arduino nano microcontroller ready for operation

6.3 Hardware implementation

The hardware implementation involves the connection of different systems components to make a physical prototype that can be tested and operated. The components were connected to make a digital tachometer as shown in figure **………..** .

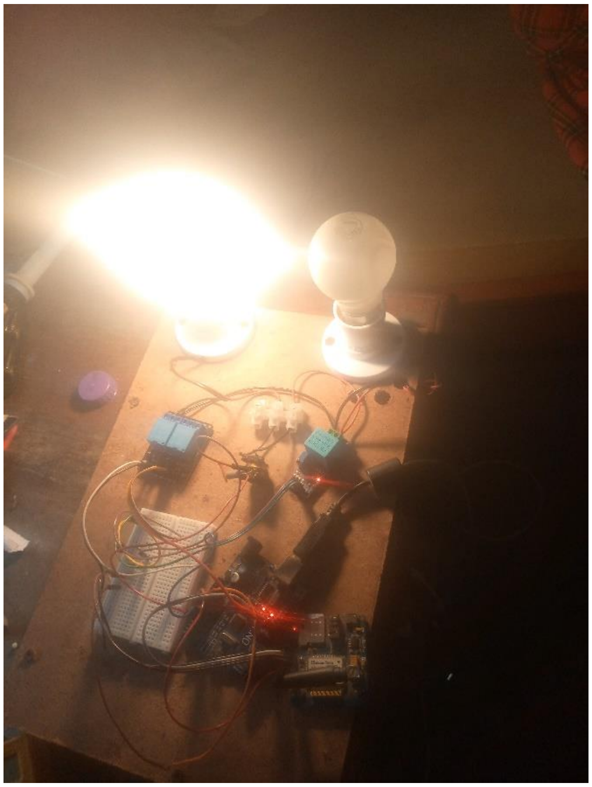
The tachometer hardware implementation involved the following procedures;

- The circuit components were fixed on the printed circuit board
- The components were connected according to the circuit design using connecting wires, soldering gun and solder wire
- The circuit was visually inspected to ensure proper connections of the components
- Digital multimeter was used to check for continuity of the connections
- The circuit was ready for testing and operation.

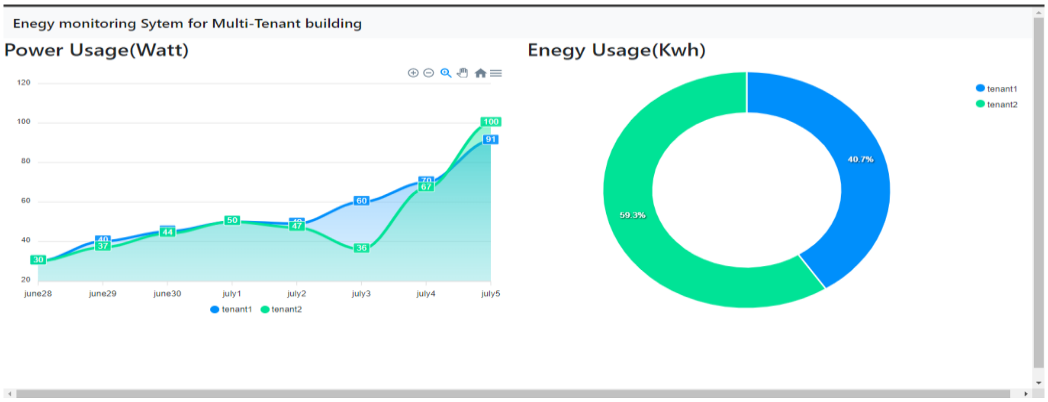
*Figure **12**: Implemented project prototype*

6.4 Testing and operation

The circuit was tested by connecting power and energy was monitored to each tenant which was presented by bulb lamp



Below is webapp dashboard of implemented user interface that user will use to interact withapp



CHAPTER SEVEN: RECOMMENDATION AND CONCLUSION

7.1. CONCLUSION.

This project has fully achieved the specified objectives. That is the Design and implementation of the Energy Monitoring System For Multi-tenant building. This system will provide a better and smart way of monitoring energy consumption in households with multi tenant through any device that have internet such as smartphones, which will lead to better and economic way of saving electric energy and energy cost.

REFERENCES

1. Gomes, Luis & Sousa, Filipe & Vale, Zita. (2018). An Agent-based IoT System for Intelligent Energy Monitoring in Buildings. IEEE Vehicular Technology Conference.

2. Magori, Bumpei& Yashiro, Tomonari. (2022). Building energy monitoring system Building energy monitoring system.

3. wikipedia. (2022, February 2 2022). *Web_application*. Retrieved from wikipedia:

   https://en.wikipedia.org/wiki/Web_application

4. botshop. (2021, February 12). *ac-voltage-sensor-pinout.jpg*. Retrieved from botshop: https://www.botshop.co.za/wp-content/uploads/2019/02/ac-voltage-sensor-pinout.jpg

Appendix 1: PROJECT BUDGET

SN	Component	Quantity	Cost per unit (Tshs)	Amount (Tshs)
1	Current sensor	2	15,000	30,000
2	Voltage sensor	1	15,000	15,000
3	Arduino	1	40,000	40,000
4	Wi-Fi module	1	35,000	35,000
5	DC Power supply	1	10,000	10,000
6	Relay	5	3,000	15,000
7	Bread board	1	5,000	5,000
8	Connecting wires	20	50	1,000
9	Cables	3	2000	6000
10	Resistors	10	100	1,000
11	Stationery		50,000	50,000
			TOTAL	**198500.00**