BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE

SMART AUTOMATIC ELECTRICITY CHANGEOVER SWITCHES

By

JAMES DAHWA

REG NUMBER B1953172

SUPERVISOR: MR. O. MUZURURA

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE BACHELOR OF SCIENCE HONOURS DEGREE IN COMPUTER SCIENCE

2022

Approval Form

The undersigned certify that they have supervised the student James Dahwa in the research dissertation entitled, "**Smart/Intelligent Automatic Electricity Changeover Switches**" submitted in partial fulfilment of the requirements for a Bachelor of Science Honors Degree in Computer Science at Bindura University of Science Education.

STUDENT: **DATE:**

………………………………………………… **…………………………..**

SUPERVISOR: **DATE:**

………………………………………………… **..…………………………..**

CHAIRPERSON: **DATE:**

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EXTERNAL EXAMINER: **DATE:**

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Abstract

Electricity (energy), which plays a major role in economic development of a nation, forms the basis of this study, with interests in human, infrastructural and economic development. In most developing and underdeveloped parts of the world, the supply of electricity for industrial, commercial and domestic use is highly unstable(Ezema et al., 2019). This gives rise to the frequent use of alternative sources of power supply to meet up with the energy demands. The introduction of these alternative sources of supply brings forth the challenge of switching smoothly and timely between the mains supply and the alternative sources whenever there is a failure on the mains source. The first objective of this study was to design and implement a changeover switch that uses a revers bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier. The second objective was to design and implement a notification module which monitors the state of the switch and send a notification if it detects an anomaly. The third and last objective was to assess the effectiveness of the use of a connected and intelligent/smart changeover switch in deciding whether to change from a primary source to a secondary source or vice versa. The researcher developed a changeover switch model that Arduino microcontrollers to detect power in a line and automatically switch to auxiliary power if power is cut which satisfies the second research objective.The model is also capable of communicating to the user of the person in charge automatically. The researcher performed all the necessary black, white box tests and performance tests using the confusion matrix, the author found that the system had satisfactory performance. The system was tested in average response time, accuracy and it achieved 1.05 seconds and 95% respectively. Therefore, providing an improvement over the results obtained by other researchers such as (Ezema et al., 2019) and (Boma & Ikwuagwu, 2021) The gained results are significant and confirm the efficiency of the use of connected and intelligent/smart changeover switch in deciding whether to change from a primary source to a secondary source or vice versa .

Acknowledgements

I would like to extend my gratitude and sincere thanks to my supervisor Mr Muzurura for his constant motivation and support during the course of my work. I truly appreciate and value his esteemed guidance and encouragement from the beginning. I also want to thanks Mr Matombo, Mr. Chaka for their co-supervision, I really appreciate all the time and efforts they put with the bid of helping me to come up with a quality research. Furthermore, I would like to mention my father, who made this all possible and also played a supporting role which contributed positively to my welfare.

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Chapter 1: Problem Identification

1.1 Introduction

Electricity (energy), which plays a major role in economic development of a nation, forms the basis of this study, with interests in human, infrastructural and economic development. In most developing and underdeveloped parts of the world, the supply of electricity for industrial, commercial and domestic use is highly unstable(Ezema et al., 2019). This gives rise to the frequent use of alternative sources of power supply to meet up with the energy demands. The introduction of these alternative sources of supply brings forth the challenge of switching smoothly and timely between the mains supply and the alternative sources whenever there is a failure on the mains source. There is also the need to reduce drudgery from switching between the two sources on the human side. Power cuts come at unexpected times, in Zimbabwe these disruption sometime result in more than 12 hours without power (Bloomberg Sept 2021). Though most cases in Zimbabwe are due to load shedding there are some cases where these outages are due to localized power failures. In times like there the time taken by power to resume is important as in big cooperates an outage translates to lost revenue. To limit this time auto changeover switches were created.

1.2 Background Of The Study

A changeover switch is a device designed to transfer house/office/business electricity supply from one (usually commercial) to a localized power supply (usually a generator or solar) in case the other fails, has an outage or power has resumed (Nelson Millers 2016). These devices work by detecting the absence or disruption of power in the primary power supply and triggers a signal which powers on the generator or solar power supplies. Their popularity has been on a steady rise, as organizations try to reduce the time between an outage and the time the local power supply takes over. These devices have also been going through various changes with some of them now housing electricity fluctuation monitors, and some also having power surge detectors.

1.3 Statement of the Problem

Though these devices have been going through a phase of changes they still may fail to detect power failures. Since they need power to operate they themselves may experience power failure which results in the failure of the whole system. They can also incorrectly detect the absence of power from the utility supplier triggering a changeover. They can do this repeatedly sending the message that there are a series of outages. These device may sometimes also fail to detect when power resumes resulting in continued use of secondary power such as a generator resulting in wasted fuel. They can also close in on the generator without disconnecting from the utility which results in a blown generator if the two are out of phase.

1.3 Aim of Research

To assess the use of connected device (IOT) and reverse bi-directional relay in automatic electricity changeover through the creation of an intelligent and connected electricity changeover switch.

1.4 Research Objectives

- To design and implement a changeover switch that uses a revers bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier.
- To design and implement a notification module which monitors the state of the switch and send a notification if it detects an anomaly.
- To assess the effectiveness of the use of a connected and intelligent/smart changeover switch in deciding whether to change from a primary source to a secondary source or vice versa.

1.5 Research Questions

- How to design and implement a changeover switch that uses a revers bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier?

- How to design and implement a notification module which monitors the state of the switch and send a notification if it detects an anomaly?
- Is the use of revers bi-directional relay effective in implementing a connected and intelligent/smart changeover switch deciding whether to change from a primary source to a secondary source or vice versa?

1.6 Research propositions/ hypothesis

- H_0: The system will accurately monitor the state of the switch and decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier.
- H_1: The system will fail to accurately monitor the state of the switch and decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier.

1.7 Justification of Research

- The delayed switching on of secondary power in the event that the primary power supply fails directly results in lost revenue for organizations.
- Also since the powering on of secondary power when it is not in phase with primary power results in lost property in case of generators and sometimes in the lost of lives of serviceman.
- The failure of changeover switches to notify of failed power resumption lead to delayed human intervention also resulting in lost revenue as this directly affect the flow of work.

1.8Scope/Delimitation Of The Research

The goal of this research is to design and implement a changeover switch that uses a revers bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier and determine the effectiveness of the use of a connected and intelligent/smart changeover switch in deciding whether to switch power.

1.9 Limitations/Challenges

Some of the restrictions that come across during this project design include the following:

- Availability of micro controllers.
- Cost of acquiring the required instruments for the development of the solution.

1.10 Definition of Terms

Electricity- a form of energy resulting from the existence of charged particles(such as electrons or protons) either statically as an accumulation of charge or dynamically as a current.

Power cut- an interruption in the supply of electricity.

Surge Detectors-an inherent feature of the surge control system which detects fluctuations in the power supply and avoid damage by shutting down the power.

Chapter 2: Literature Review

2.1 Introduction

A literature review, according to (Puebo, 2020), is a scientific study prepared from published sources that summarizes current understanding on a given issue. In this chapter, the researcher concentrates on answering the research questions and reveals previous and current systems that are similar to the research project at hand that have been done by other authors. This will be extremely valuable to the author because it will serve as a guide to identifying solutions, strategies, and techniques utilized by prior writers to solve earlier research problems. It is a tool that informs the researcher if the study proposal is possible based on the findings of previous researchers in that field. This chapter, in accordance with the definition of a literature review, provides information on how others have implemented a connected and intelligent/smart changeover switch.

2.2 Electricity Generation in Zimbabwe

Zimbabwe relies on hydroelectric power. In rural parts of the country, 80-90% of the people depend on wood fuel and kerosene for cooking lighting. Food processing tasks like milling grain are usually carried out with diesel-powered system. Total electricity generation in 2009 was 7,900 gigawatt hours (Gwh). 53% of this was produced from renewable sources. Electricity consumption per capita in 2009 stood at 1,022-kilowatt hours (kWh). 33.9% of this total installed capacity was from hydroelectric plants. According to WEC (2013), the installed capacity of hydropower in Zimbabwe by 2011 was 754 MW. In 2015, 504 ktoe of hydroelectricity was produced out of a total of 762 ktoe of electricity produced (AFREC, 2015). The potential for small hydro power is 120 MW (REEEp, 2012) with some already connected to the grid such as the grid-connected 750 kW privately owned Rusitu Mini hydro plant on the Nyahode river and the 30 MW Gairezi plant located in Nyange district in the east of the country (REEEP, 2012). Zimbabwe is a member of the Southern African Power Pool. Imports of energy from neighboring countries are not enough to solve the under capacity problem and lack of electricity hampers economic growth. A second interconnector with South Africa is in advanced planning stages, according to PIDA, the Programme for Infrastructure Development in Africa. Construction of the Zimbabwe section of the 320 km/ 400 kV South Africa to Zimbabwe transmission interconnector will form part of the total 935 km project across Mozambique, Zimbabwe and South Africa(Ishioma, 2020).

The demand for electricity in Zimbabwe significantly exceeds the available internal electricity generation capacity. While the average ‘suppressed’ electricity system maximum demand is about 1600 MW, the average internal generation capacity reported in the ZETDC daily power supply status hardly reaches 1000MW. Thus, there is significant unmet demand, resulting in load shedding and expensive electricity imports from neighbouring countries such as South Africa and Mozambique. However, Zimbabwe has installed electricity generation capacity of 2306 MW. The system maximum demand is rather suppressed in the sense that the country is and has been operating at a low industry capacity utilisation.

2.3 Stand-By Power Unit/Secondary Power Source (Generator)

Zimbabwe has a considerate population using generators as back-up power/secondary power source(Mati, 2020).Due to the unreliability of the ZESA power, businesses and households have no option but to use generators. The stand-by generator set is commonly used to supply emergency power to most of the power consumers where the mains supply is unstable. The type of generator, engine type, its cooling system and fuel, the load capacity and the operating environment. Whatever cooling system is used to cool the generator, it is recommended that the heated air be channelled outside through an exhaust pipe while provision should be made to bring in fresh air so that the generating room, where the generator is installed, can be kept from becoming excessively hot, as this might cause damage to the engine of the generating set. Furthermore, the lubrication of the set is much important; the recommended lubricant should be used in order to maintain smooth and prolonged life span of the set by reducing wear and tear of the engine and other parts due to friction. Finally, it is important to determine the correct rating of the mechanical engine to drive a given generator so that it has the minimum capacity necessary to supply the selected load.

2.4 Arduino Controller

Arduino is a physical computing platform based on a single microcontroller board that is open-source. When there are interactions between inputs and outputs, Arduino is used. It is used to regulate the output in response to the input commands, such as switching on or off a light or motor. Wiring, an integrated development environment (IDE), and a single board microcontroller are used in the Arduino programming language. Because of its inexpensive cost, wide range of applications, great quality, and ease of availability, the Arduino controller was chosen for this project. Buttons, LEDs, motors, speakers, GPS devices, cameras, the internet, and even your smartphone or television may all be controlled with Arduino. Because of this flexibility, as well as the fact that the Arduino software is free, the hardware boards are relatively inexpensive, and both the software and hardware are simple to learn, a large community of users has contributed code and released instructions for a wide range of Arduino-based projects. Arduino is an open-source computer hardware and software company, project, and user community that creates microcontroller-based kits for creating digital gadgets and interactive things that can sense and control real items (Bhatia & Gupta,2015).Massimo Banzi helped invent the Arduino, a tiny, easy-to-use open-source microcontroller that has inspired thousands of people around the world to make gadgets that range from toys to satellite gear. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on the Processing project, which includes support for the C and C++ programming languages.

2.4.1 Physical Characteristics

The maximum length and width of the Arduino Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins(Murphy,2011).The Arduino Uno is an ATmega328-based microcontroller board (datasheet). It contains 14 digital input/output pins (including 6 PWM outputs), 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It comes with everything you need to get started with the microcontroller; simply plug it into a computer via USB or power it with an AC-to-DC adapter or battery. The Uno is unique in that it does not employ the FTDI USB-to-serial driver chip found on previous boards. Instead, it uses an

Atmega8U2 that has been coded to act as a USB-to-serial converter. The figure below shows the Arduino uno microcontroller board.

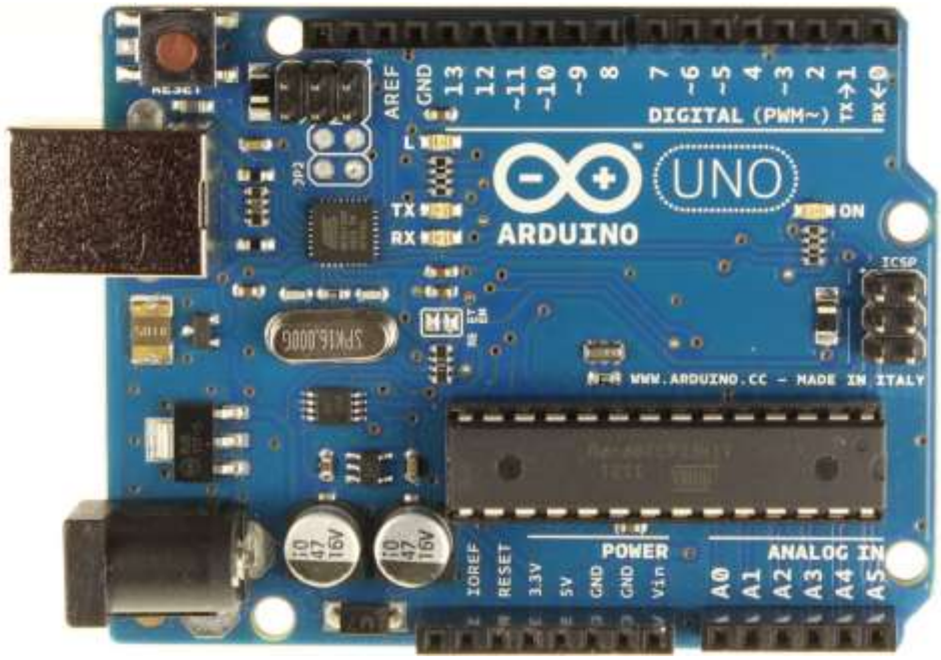


Figure 1:Arduino Uno Microcontroller.

2.5 Reverse Power Relay

The reverse power relay is a directional protective relay that prevents power from flowing in the reverse direction. The relay is used in installations where a generator runs in parallel with the utility or another generator so as to prevent power from the bus bar or another generator from flowing back to the active generator when its output fails(Sudharchand,2019). The relay monitors the power from the generator and in case the generator output falls below a preset value, it quickly disconnects the generator coil to avoid power from flowing into the stator coil. The generator output can fail due to problems with the prime mover, turbine or engine that drives the generator, issues with speed controller, or different frequencies during synchronization. When the prime mover fails, the generator stops producing power and may instead start drawing power from the other parallel sources and start motoring(Sudharchand,2019). The reverse power relay senses any reverse direction of power flow and disconnects the generator to avoid any possible damage.

2.5.1 Reverse Power Relay Construction And Operation

The relay is made of a lightweight non-magnetic aluminum disc between two soft laminated iron core electromagnets, and fixed on a spindle running on low friction bearings. The upper electromagnet is wound with a voltage coil which is then supplied from one phase and an artificial neutral of the generator output. The other magnet has a current coil from supplied from a current transformer connected to the same phase as the voltage in the upper electromagnet.The voltage coil has a high inductance, designed in a way that the voltage lags the current in the coil by about 90 degrees. This lag ensures that the magnetic field generated from the current in the upper coil lags the magnetic field produced by the current in the lower electromagnet(Sudharchand, 2019).The two magnetic fields which are out of phase, produces eddy current in the aluminium disc, and this creates a torque that tries to rotate the disc. Under normal condition when power is flowing as expected, the trip contacts of the relay are open, and the disc is against a stop. If a reverse power starts to flow, the disc rotates in the opposite direction, moves away from the stop and towards the trip contacts that activates the trip circuit.

2.6 Directional & Non Directional Relays

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

Non Directional relay: When there is fault in power system, power flows through fault. Non directional relays operate irrespective of direction of flow of current.For example, breaker at generator end. If there is fault on generator secondary relay has to operate to open GT breaker.If there is fault in windings of generator and it's drawing power from grid then also GT breaker has to operate. So we use a non-directional relay. It has to operate in fault conditions irrespective of direction of power flow.

Directional Relay: Directional relay operates when the fault is driving power to flow in particular direction. It senses the direction of current flowing. For example, consider a three phase synchronous motor. Assume fault on the system. Power supply to motor is not available. But 3-phase armature is rotating in magnetic field due to inertia. So motor starts generating power. Which feeds fault. To avoid this, Directional Relay is used.A directional relay uses an additional polarizing source of voltage or current to determine the direction of a fault. Directional elements respond to the phase shift between a polarizing quantity and an operate quantity. It recognizes the direction in which fault occurs with respect to the location of relay. It is set such to actuate for faults occurring in one particular direction only.

2.7 Review Of related Literature

According to Oladokun (2013), uninterrupted continuous power supply is essential to the industrial sector, university operations, and residential sector. These standby power supply systems are used to supply power to several types of loads such as: Essential Loads particularly in industrial processes where they require high restarting times or high shut down times. So the automatic transfer from the main supplies to the standby generator must be available, Critical Loads such as elevators, or lighting in the buildings where the automatic changeover is very important especially in hospitals, malls, and public places, Sensitive Loads such as computers, equipment and appliances in hospitals, microprocessor, controlled industrial machines, and the monitoring system where it is costly to shut them down and may be required to use of Uninterrupted Power Supply.

Boma & Ikwuagwu(2021) carried out a research based on developing an automatic single phase changeover using bluetooth trigger. The automatic changeover system had immense advantage in every area where uninterrupted power is required. Whenever the reliability of electrical supply from the utilities is low and wherever continuity of supply is necessary, the automatic changeover system using bluetooth trigger switches to an alternative source from main supply and vice versa. Their paper designed a low-cost automatic changeover system using bluetooth trigger that can be used mainly in residential building; this system can be used and the specifications adhered to, the materials used if the project is to be implemented should be of high quality(Boma & Ikwuagwu, 2021).

Kolo(2007) developed automatic power changeover switch using a relay switching circuit.The project was designed for power supply applications. It involves automatic changeover between the main power supply and an auxiliary power supply, such as a generator. The project implements an automatic switching or starting of the power generator whenever the main power fails. The circuit of the project consists of logical control unit and relay switches. The design of the project takes into consideration practical or real life situations, even though it is a prototype design. Irrespective of that fact, a lot of precautions were put in place to make its performance acceptable. The basic operation of the project is to switch ON an auxiliary power supply (like a generator)(Kolo, 2007). This operation connects the power supply from the generator to the load after a predetermined time interval. This was intended to normalize the current from the generator. Switching is possible through the use of the relays(Kolo, 2007).

Ezema et al., (2019) developed an automatic change over switch with generator control mechanism. In their paper, they provide an automatic switching mechanism that transfers the consumer loads to a power source from a generator in the case of power failure in the mains supply. The solution automatically detects when power has been restored to the mains supply and returns the loads to this source while turning off the power from the generator set. The mechanism was tested and we recorded a great result. It thus holds an important key in the provision of a continuous power supply through a near seamless switching between the mains supply and an alternative standby source like the generator set(Ezema et al., 2019).

2.4 Chapter summary

The author was successful in obtaining and collecting relevant information and data for the research topic. Some of the concepts employed by the researcher came from a variety of places, including academic papers, textbooks, and the internet, which revealed holes that needed to be filled. The information gathered from all of these sources will be utilised in the preceding chapters of the study to meet the research project's objectives. The author seeks to cover the shortfalls of the above literature by using a reverse bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier.

CHAPTER 3: METHODOLOGY

3.0 Introduction

Research is a fact-finding activity that includes scientific research or an in-depth analysis of a particular issue of interest. Depending on whether the research is exploratory, descriptive, or diagnostic, quantitative or qualitative methodologies are used. When it comes to making economic decisions, research has shown to be a significant tool for government institutions and policymakers. Mackey and Gass (2013). Methodology is defined as the systematic, theoretical analysis of the methods or procedures applied to a particular field of study. The author will define approaches used to attain the proposed research and system objectives in this chapter. The author will create the necessary procedures to build a solution and be able to choose among competing strategies to achieve the research's desired results using the information obtained in the previous chapter. To make the study procedure easier, secondary data was used for analysis. The information for this study was gathered through official sources, the internet, and journals.

3.1 Research Design

The study's architectural backbone is research design (Moule & Goodman, 2013). According to Polit and Hungler (2014), research design refers to the strategy for answering research questions and managing problems throughout the study process. A researcher can employ one of four research models: observational, experimental, simulation, or derived. Because the application must be constructed and regularly tested to verify whether it is generating the desired effect, the researcher chose to use both experimental approaches.

3.2 Requirements Analysis

Requirements analysis is crucial to a project's success or failure, and the created requirements must be practical, documented, tested, executable, traceable, and measurable, as well as related to identified business needs and precise enough to make system design easier (Abram Moore, Bourque, & Dupuis 2004). As a result, it's critical to document all of the required system's functional and non-functional specifications at this point. To create uniform and unambiguous requirements, the acquired requirements are reviewed, revised, and scrutinized.

3.2.1 Functional Requirements

These can be characterized as a system's or component's function. A function is made up of three parts: inputs, behavior, and outputs. "Functional requirements are those acts that a system must be able to accomplish, without regard for physical limits," Bittner explained. Computations, specialized subtle elements, data control and preparation, and other specific functionalities that define what a system should achieve are examples. Use cases depict the behavioral conditions that apply to the great majority of instances in which the system applies the functional requirements.

The proposed system must be able to meet the following requirements:

i. decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier.

ii. to compare the input from various sources and perform the given action

iii. to fetch necessary information on the voltage of the power source

3.2.2 Non-Functional Requirements

They are often referred to as quality requirements and used to judge the performance of a system rather than its intended behavior. The proposed system must be able to meet the following:

i. High performance

ii. Flexible

iii. Quick response time

3.2.3 Hardware Requirements

- Core i5 processor or better
- Arduino microcontroller
- 2-channel SPDT(Single Pole Double Throw) relay (Electromechanical relay)

3.2.4 Software Requirements

- Windows 10 Operating system
- Visual Studio Professional 2020
- Microsoft Visual C#

- .Net Framework 4.5.2
- Tomcat server

3.3 System Development

This system describes the overview of the system and how it was developed so as to produce the results. It specifies all the software tools and models used in the development of the system.

3.3.1 System Development tools

3.3.2 Rapid Prototyping

Rapid prototyping is an agile strategy used throughout the product development process. With this approach, 3-dimensional prototypes of a product or feature are created and tested to optimize characteristics like shape, size, and overall usability. Prototyping is a way to validate the hypothesis that a product will solve the problem it is intended to solve. Although not fully functional by any means, a prototype often "looks" real enough that potential users can interact with it and provide feedback. If the feedback reveals that the prototype is pretty far off the mark, then the company saves weeks or months from building something that won't work in the real world. At the same time, a positive reaction to a prototype indicates the product concepts are on the right track, and development should proceed. The "rapid" part of this comes into play with the speed that the initial prototype can be produced, how quickly feedback can be gathered and synthesized, and how fast subsequent iterations can go through the same process as shown in the figure below.

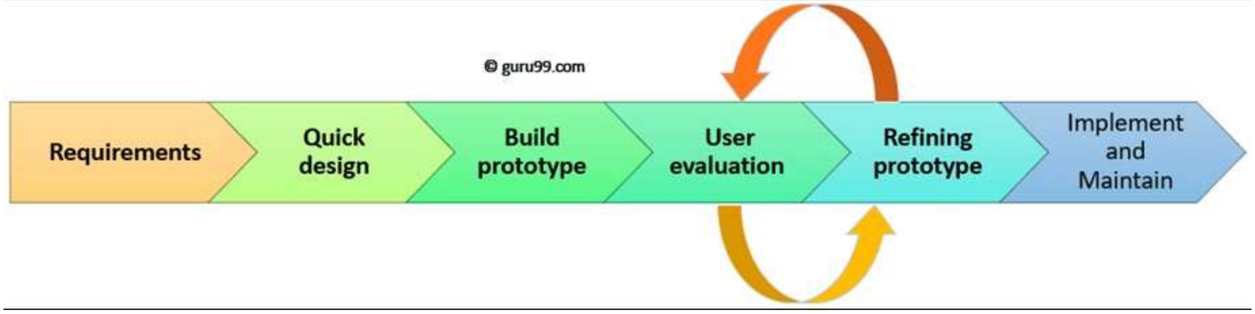


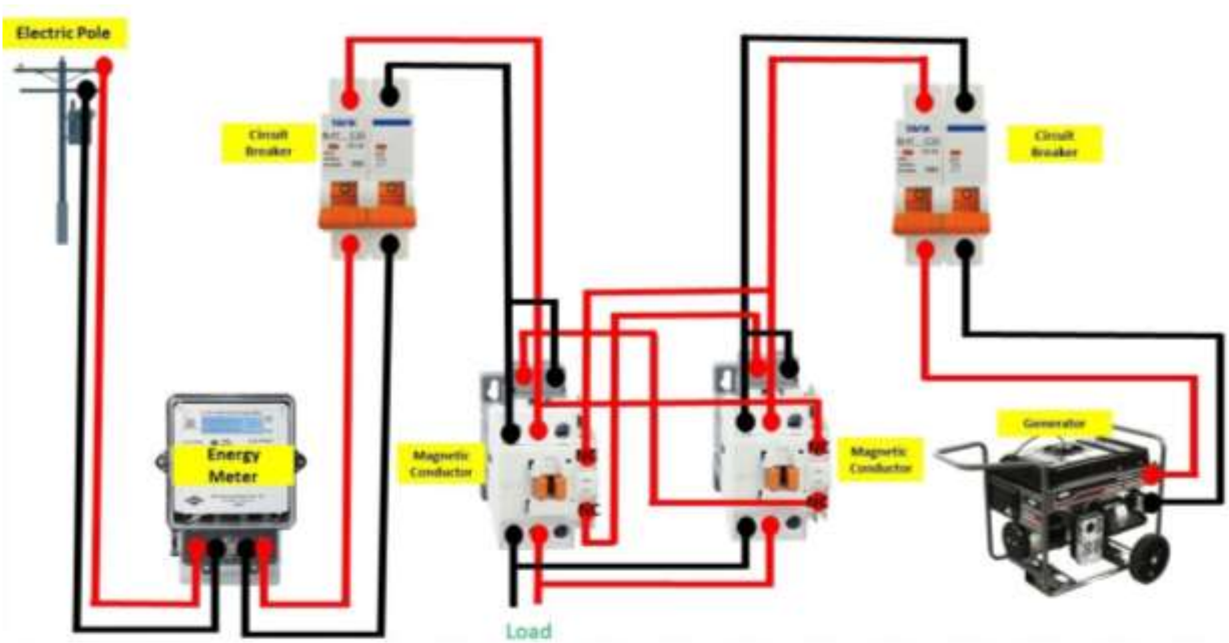
Fig 3: prototype

3.4 Summary of how the system works

The system is demonstrated using an Arduino microcontroller and Arduino microcontroller and a 2-channel SPDT(Single Pole Double Throw) relay. The system is tested using two channels of power, the first one as the main utility electricity and the second one as the backup power. When the main power is turned off, the system automatically switches on the backup power.

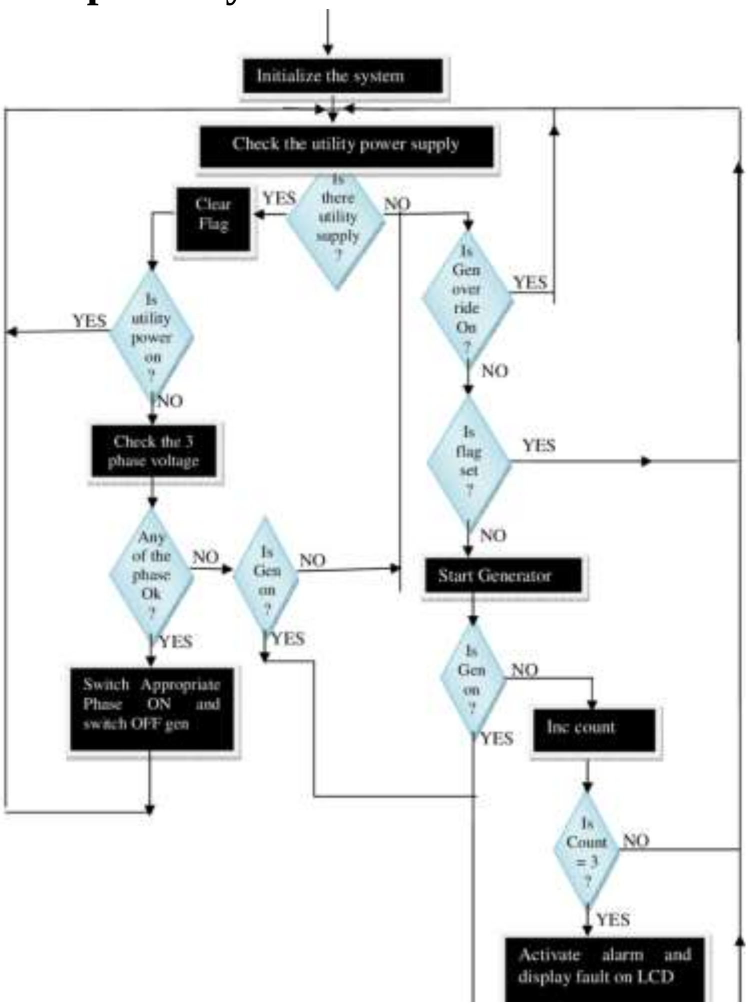
3.5 System Design

3.5.1 System Connection diagram (CDs)



Load
1589.56
COM
Automatic Tranfer Switch
Main Power Supply
(EB)
Backup Power Supply
(DG)

3.5.2 Proposed System flow chart



3.6 Implementation

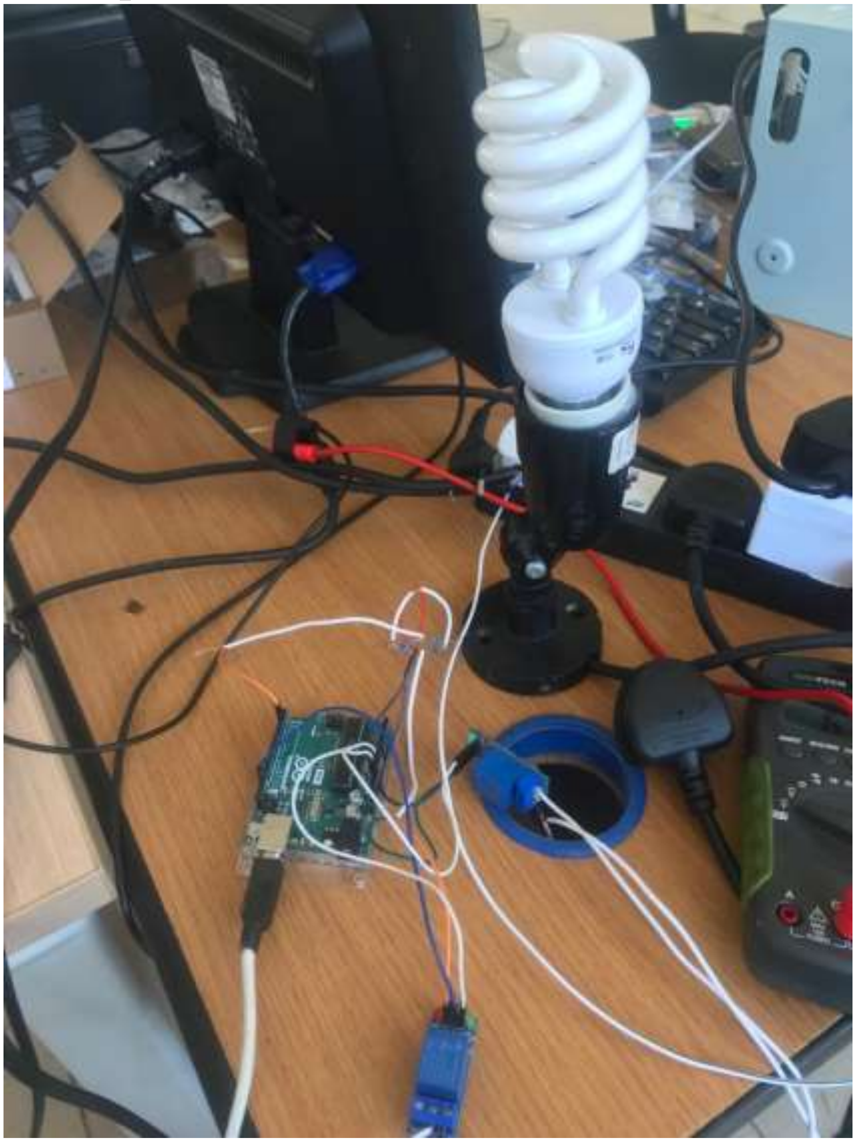


Figure 2:System Setup

As seen from the above diagram, the system is simulated using an Arduino microcontroller and Arduino microcontroller and a 2-channel SPDT(Single Pole Double Throw) relay. The system is tested using two channels of power, the first one as the main utility electricity and the second one as the backup power.

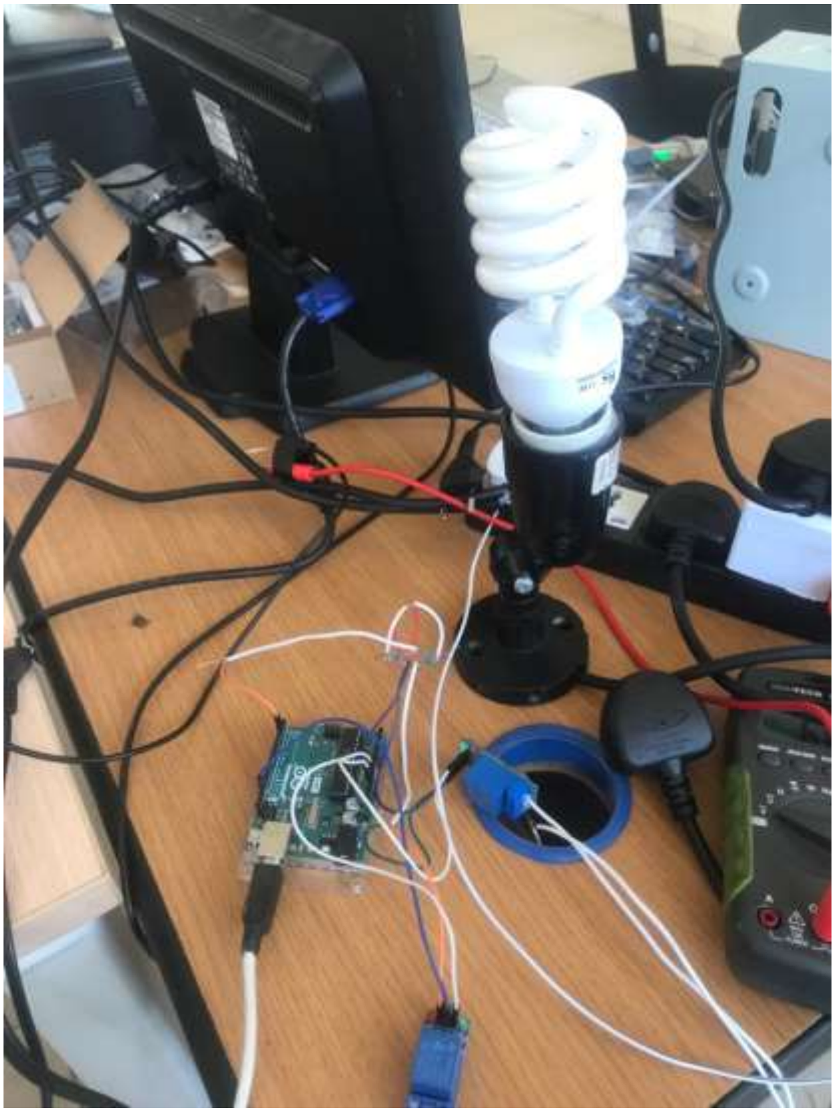


Figure 3:System setup with bulb as testing element

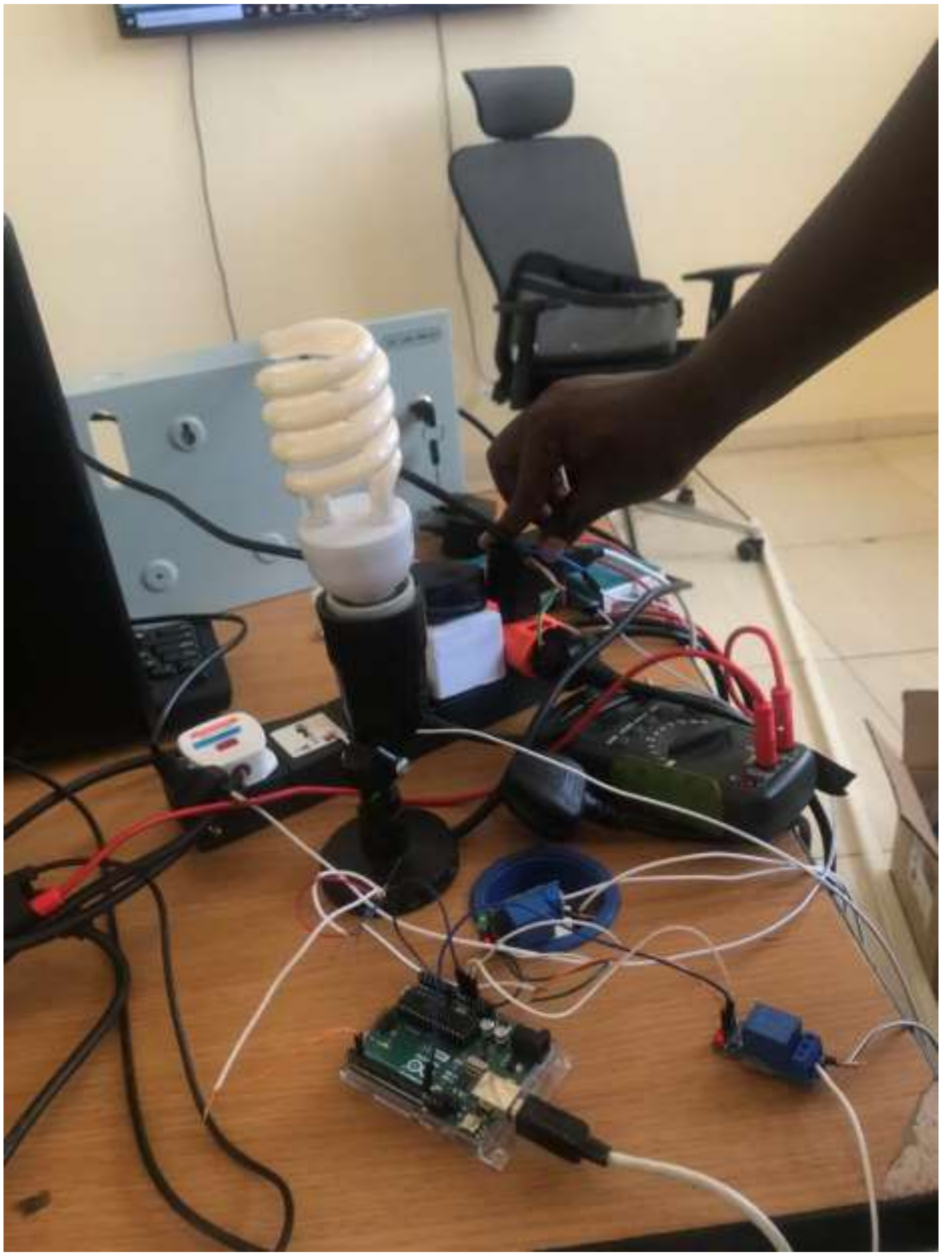


Figure 4:Connecting to power

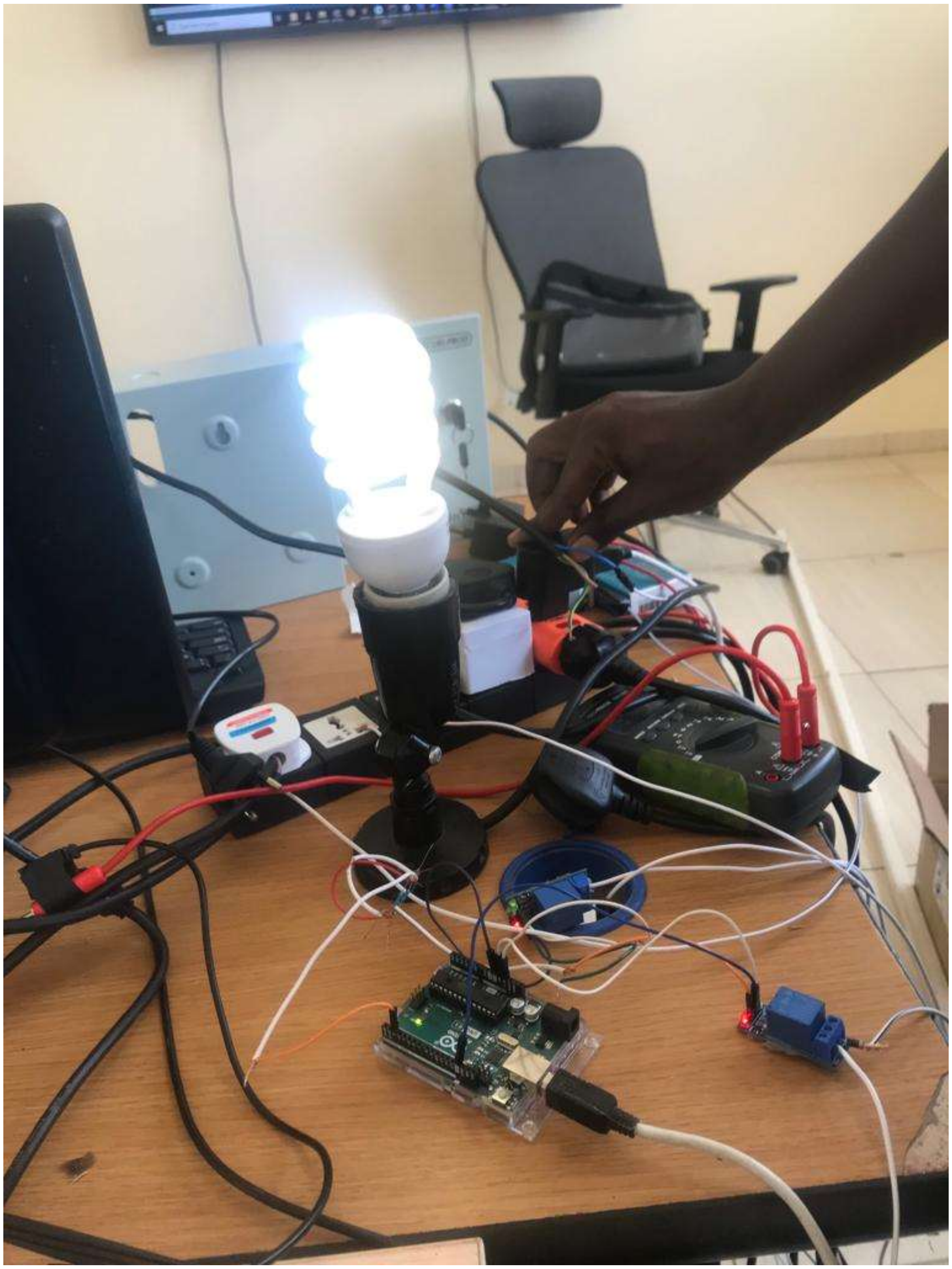
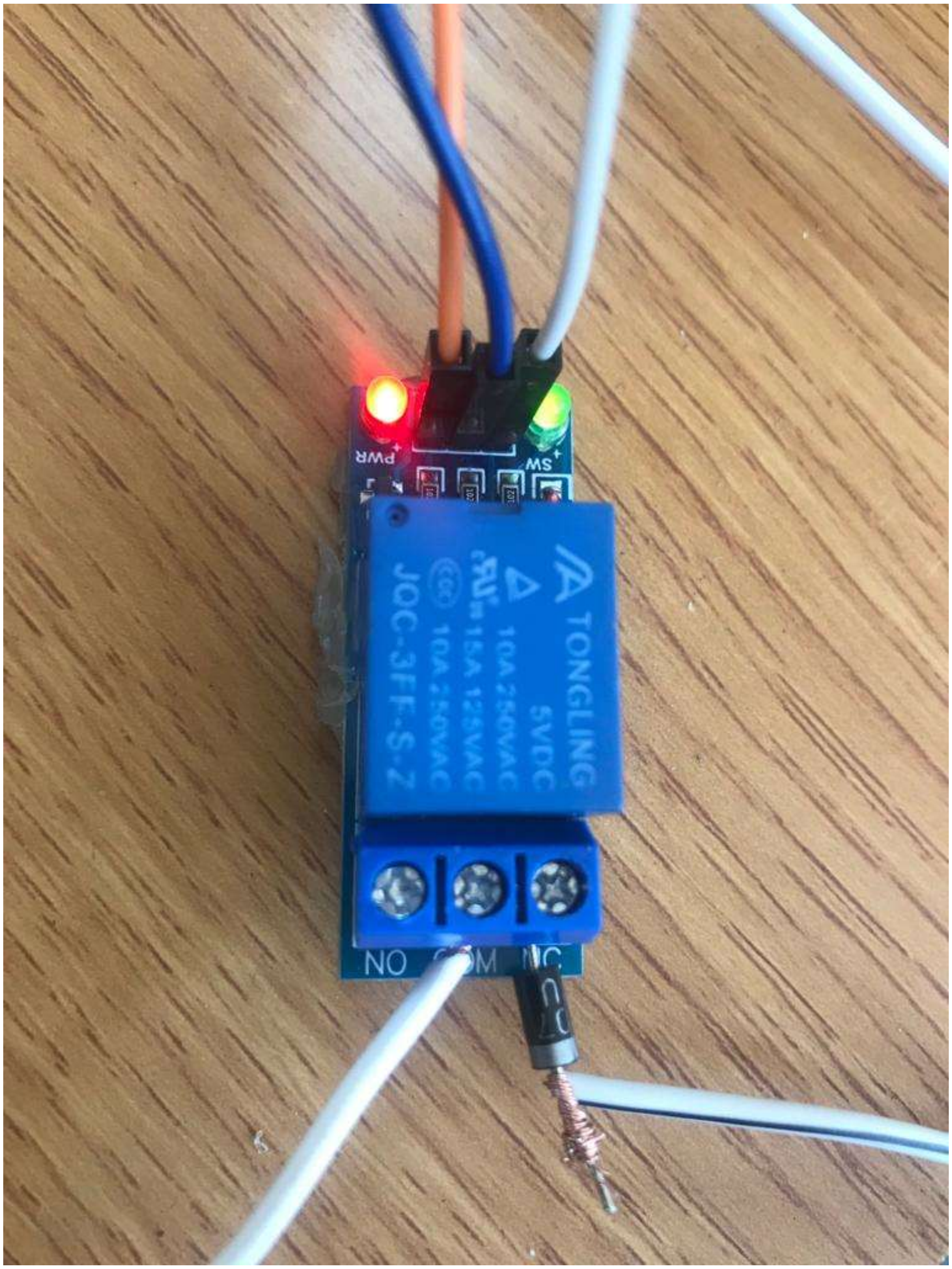
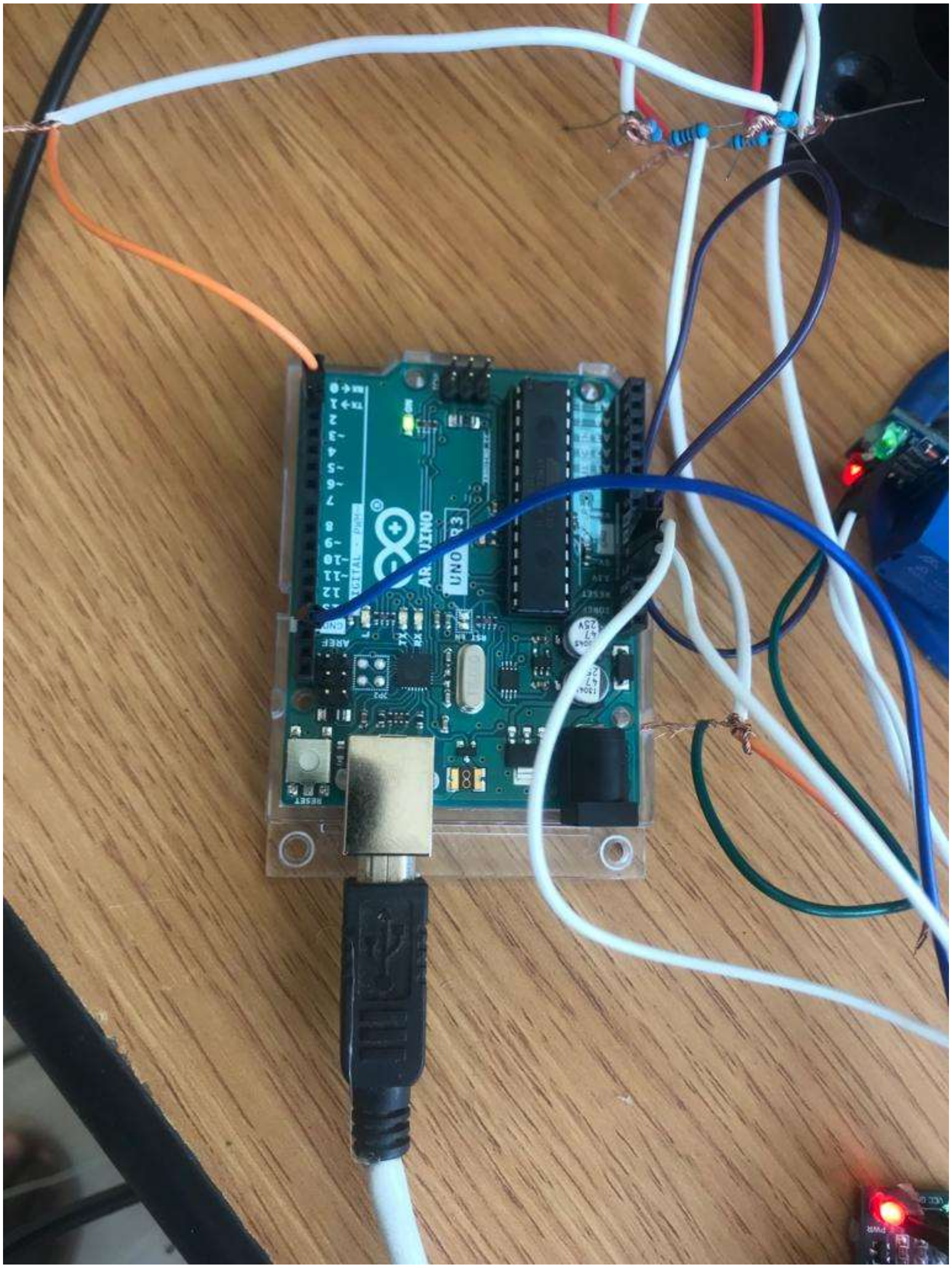


Figure 5:Power switching on the bulb

When the main power is turned off, the system automatically switches on the backup power.


PWR
SW
TONGLING
5VDC
10A 250VAC
15A 125VAC
10A 250VAC
JQC-3FF-S-Z
NO
NC



3.7 Chapter Summary

The chapter mainly focused on the methods and tool that were used to develop the model. Thus, different techniques and methods were used in developing the model up to the end.

CHAPTER 4: RESULTS

4.0 Introduction

In the time of completion of the system, there was need to analyze the effectiveness and efficiency of the developed solution to the system. Performance, accuracy and response time were the measures used to determine the efficiency and effectiveness of the developed system. Results were obtained from data collected from the previous chapter through analysis. Determining different behaviors of the system was obtained was determined by white box, black box and unit testing given different scenarios.

4.1 System Testing

Testing is essential in system development, when a system has been developed it has to be tested. This chapter shows tests that where undertaken and the results that were produced, test conducted mainly focus on functional and non-functional requirements of the proposed solution.

4.1.1 White Box Testing

Black box testing is the method that does not consider the internal structure, design, and product implementation to be tested. In other words, the tester does not know its internal functioning. The Black Box only evaluates the external behaviour of the system. The inputs received by the system and the outputs or responses it produces are tested. The author conducted a black box testing on the model and got the results as follows. Therefore, the system will be tested for its effectiveness in timely changeover. The author, conducted a black box testing on the model and got the results as follows:

4.1.2 Black Box Testing

White box testing is the software testing method in which internal structure is being known to tester who is going to test the software. Generally, this type of testing is carried out by software developers. Programming and implementation knowledge is required to carry out white box testing. Testing is applicable on lower level of testing like unit testing, integration testing. In white box testing is primarily concentrate on the testing of program code of the system under test like code structure, branches, conditions, loops etc. The main aim of white box testing to check on how system is performing. The developer tested the model as shown below;

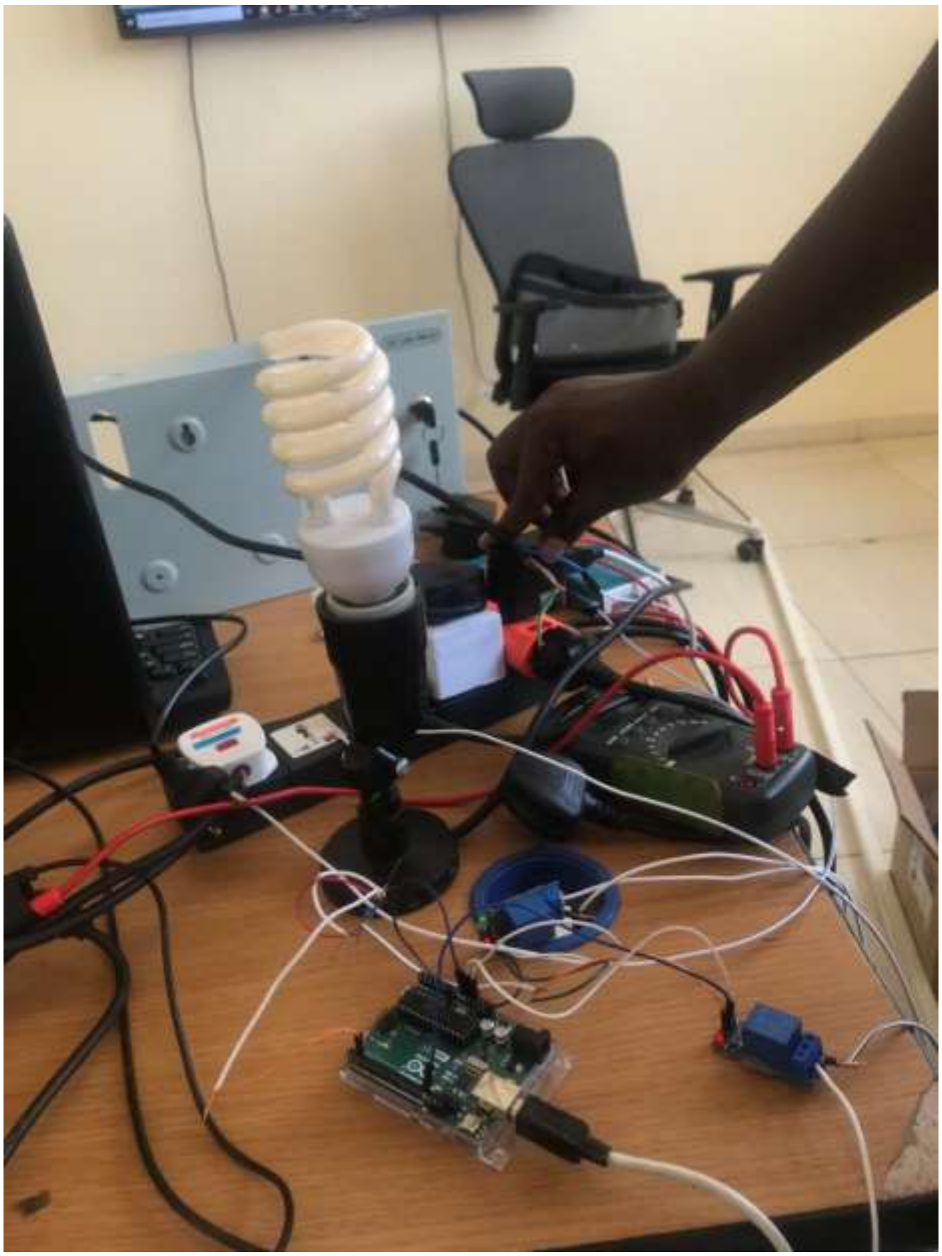


Figure 6:Connecting to power

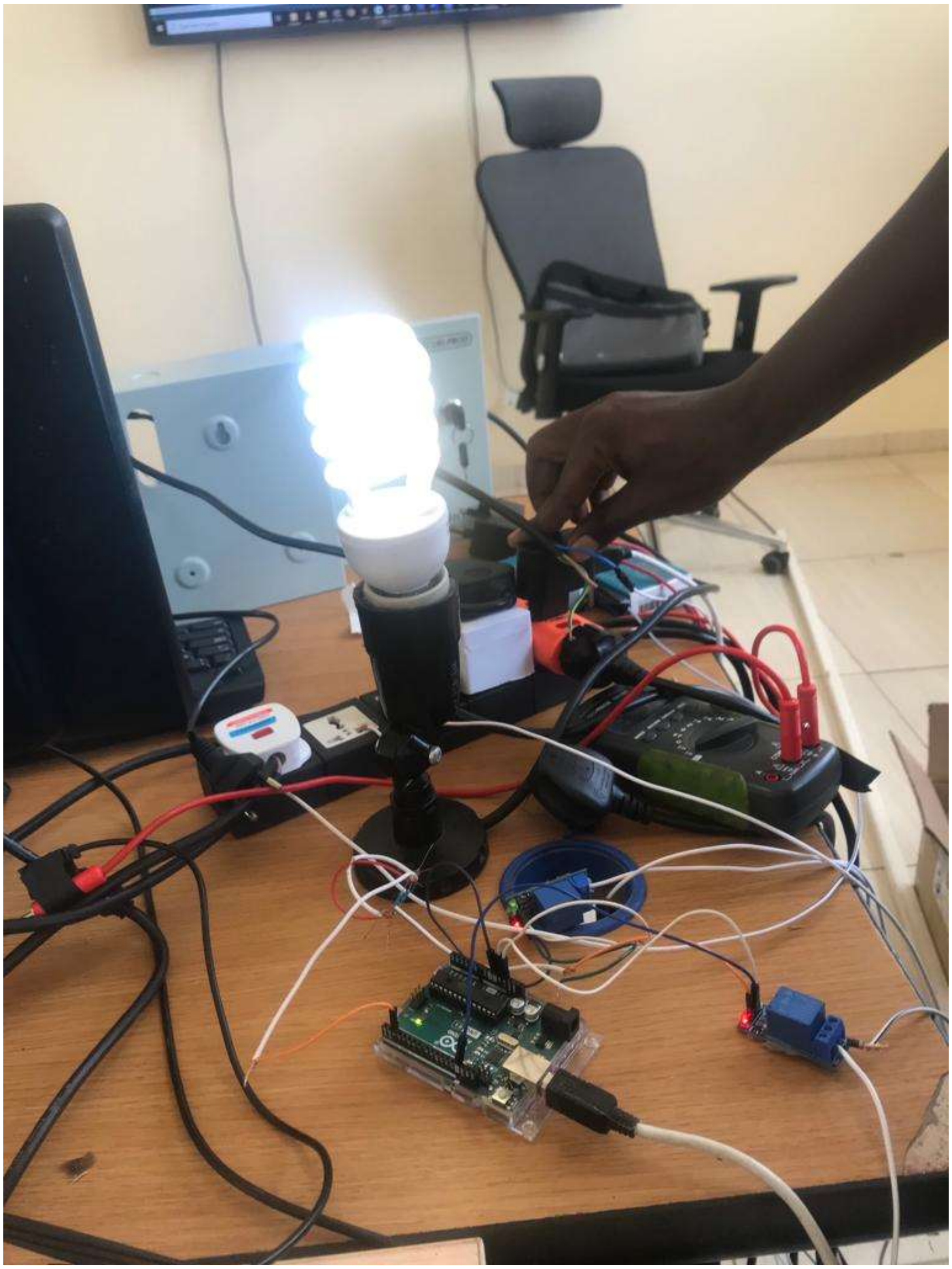
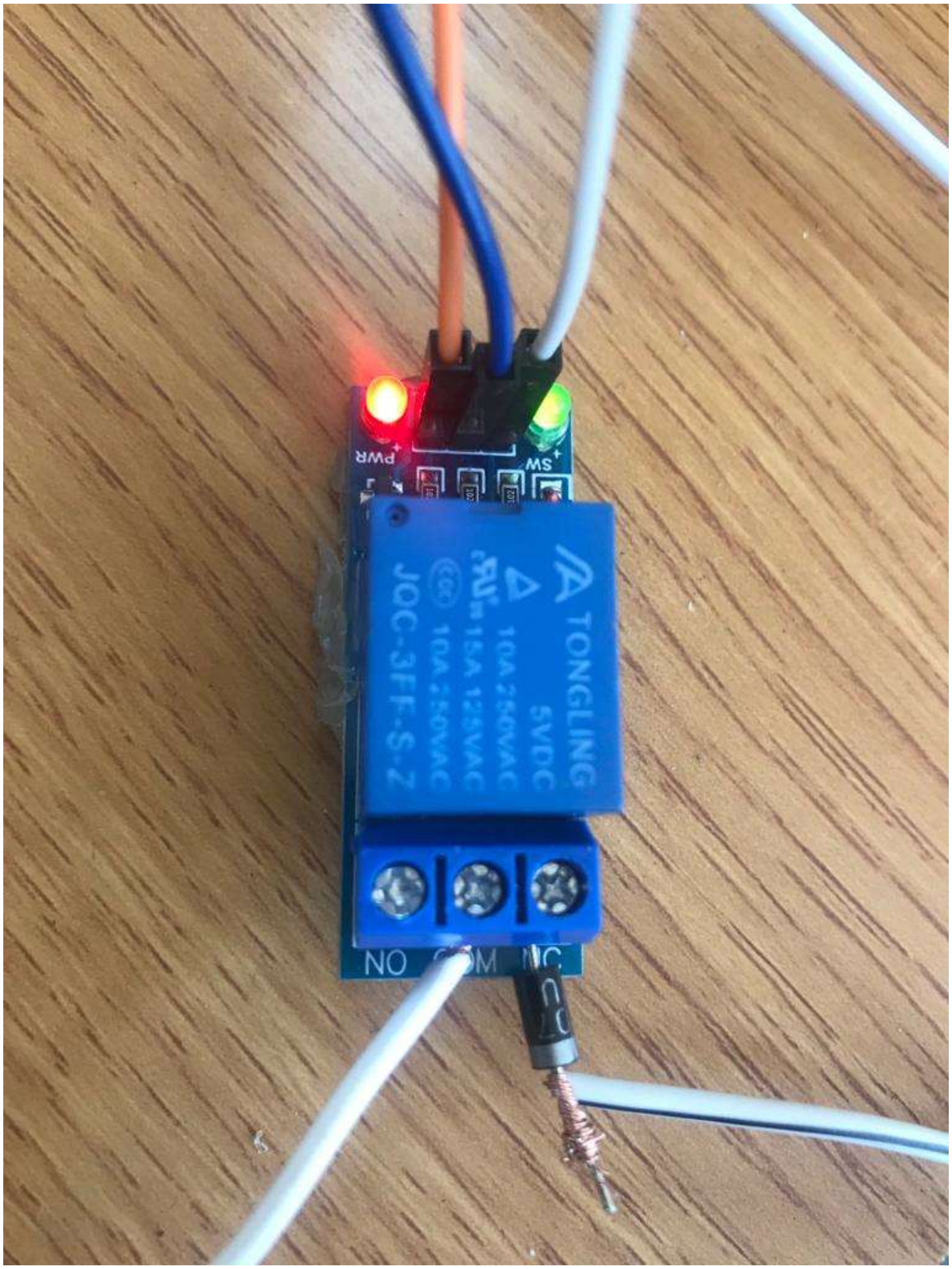


Figure 7:Power switching on the bulb

When the main power is turned off, the system automatically switches on the backup power.



4.2 Evaluation Measures and Results

A model’s performance is measured using an evaluation metric (Hossin & Sulaiman, 2015). Furthermore, model assessment metrics may be classified into three kinds, according to Hossin & Sulaiman (2015): threshold, probability, and ranking. The system's capacity to reliably switch to another power supply due to a cut in the main supply is used to assess its performance. The author utilized the confusion table in table 1 below to test the system's correctness.

4.2.1 Confusion Matrix

The confusion matrix is a table that shows the number of categories that have been assigned and those that have been anticipated. The table is used to define the model's performance.

True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) are the four terminologies used.

TP denotes situations that are genuinely true and that the test has done, whereas TN denotes numbers that are untrue and that the test has resulted as false.

FP-Are those that the test shows as true, but which are actually untrue.

FN-Numbers that the test shows as false but are really correct.

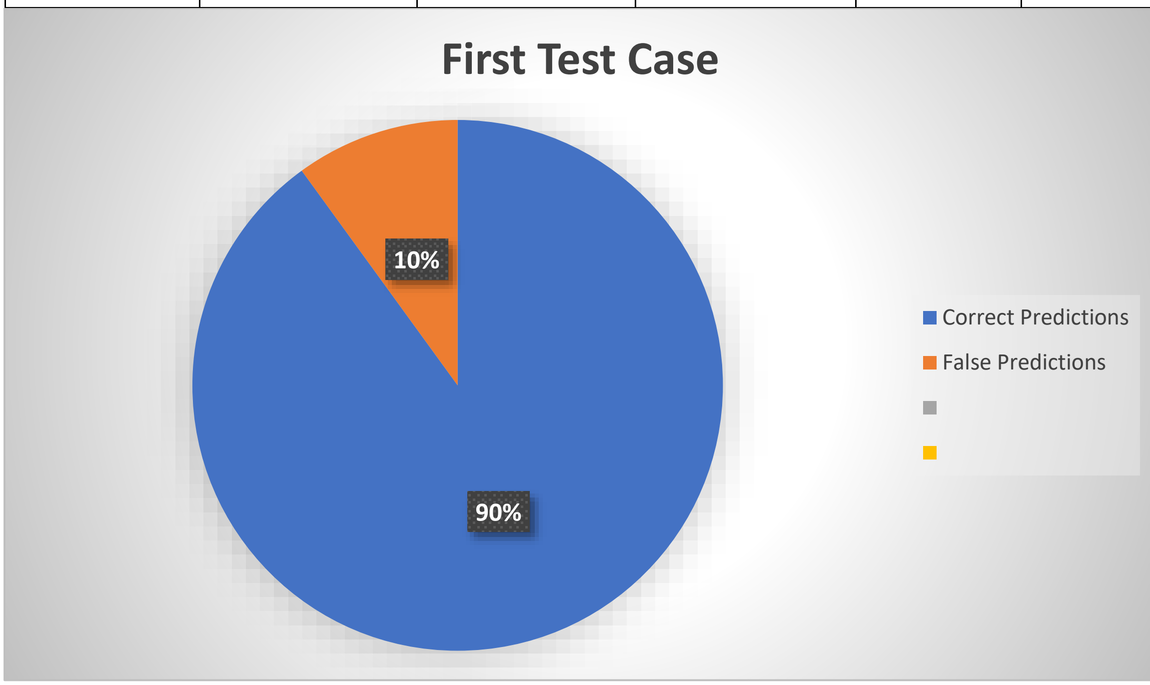
Type	Returned number of correct switches	Returned number of incorrect switches
1	True Positive	False Negative
2	False Positive	True Negative

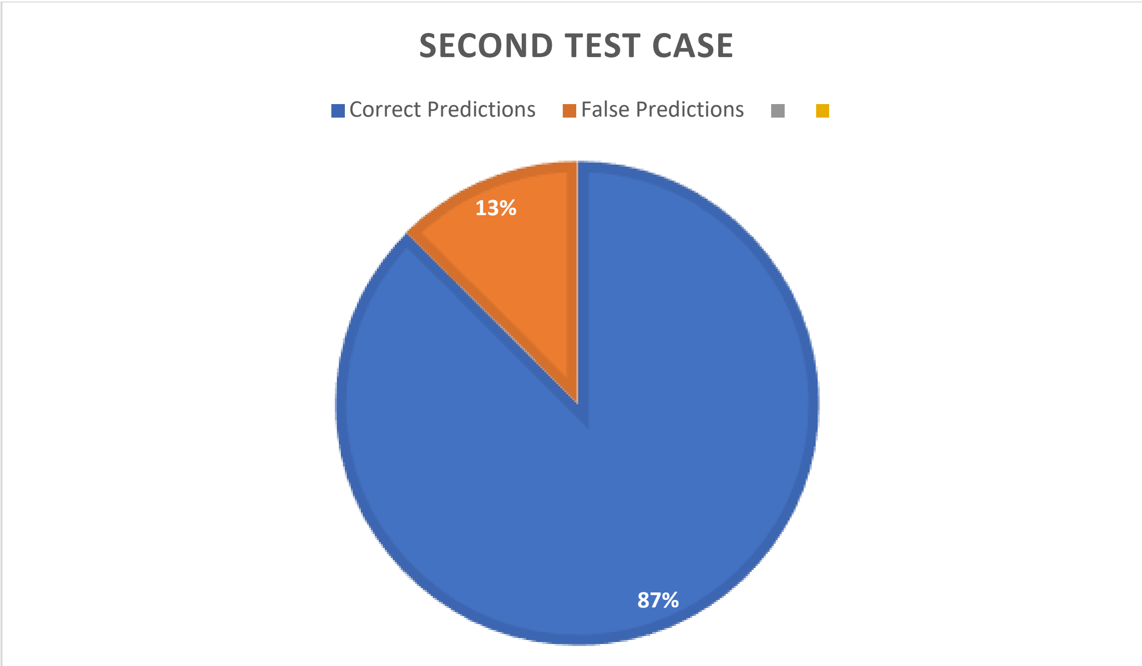
Table 1 Confusion Matric

The technology was put to the test in terms the returned number of correct and incorrect switches. For the purpose of observing the system's findings, three scenarios and a test environment were developed. The system was observed 40 times on each scenario using different testing devices as well as different power supply sockets. All of the scene analysis was done to ensure that the answer was accurate and that false switches were identified. The tables below indicate the outcomes of the tests that were conducted.

Table 2 Confusion matrix for changeover switch testing

Test cases	Switches made	Number of tests	Correct readings	False Readings	Classification
1	Yes	40	36	4	True positive
2	No	40	35	5	True negative





4.3 Accuracy

The number of correct predictions divided by the total number of switches in each category equals accuracy. The percentage of accuracy is then calculated by multiplying it by 100. The following equation is used to compute it:

Equation 1: Accuracy calculation as adopted from Karl Pearson (1904)

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} * 100$$

$$\text{Accuracy rate} = \frac{36 + 35}{36 + 35 + 5 + 4} * 100$$

$$\text{Accuracy} = \frac{71}{80} * 100$$

$$\text{Accuracy} = 88.7\%$$

Accuracy: Real-time Stress testing

The table illustrates the tests conducted.

Table 2: Real-time stress testing

Number of switches[N]	**Received [1] / Not-Received [0]**
1	1
2	1
3	0
4	1
5	1
↓	↓
12	1
13	1
14	1
15	1

↓	↓
18	1
19	1
20	0
21	1
22	1
23	1
↓	↓
40	1

Accuracy = N – X / N *100

Where X is the number of no switches:

= **40 – (2 / 40) * 100**

= **<u>95%</u>**

The author concluded that the system is highly unlikely to fail recording switches automatically accurately hence the 95% accuracy.

4.4 Response Time

Response time refers to the time it takes the system to switch over power to backup power after detecting power loss in the main power line. It is used as a measure of system performance. To test for the system response time the author used the average and the peak response times to determine the overall performance of the system. The average response time involves taking a series of time reading that is the time it takes the system switch over power and calculate their total and divide it by the total number of readings. The peak time is taking the highest valued reading which is also considered the worst-case response time.

Table 3 System response times

Test	**Reading Time in Seconds**
1	1.9
2	1.4
3	0.9
4	2.1
5	0.7
6	1.5
7	0.8
8	0.8
9	0.7
10	0.9
11	1.4
12	1.2
13	1.0
14	0.7
15	0.7
16	0.8
17	0.6
18	1.9
19	1.1
20	0.7

All the readings where rounded to the nearest one decimal place.

Average system response time = sum of all response time/ number of readings

= (0.7+1.1+1.9+0.6+0.8+0.7+0.7+1.0+1.2+1.4+0.9+0.7+0.8+0.8+1.5+0.7+2.1+0.9+1.4+1.9)/20

= 21/20 = **1.05 seconds**

4.5 Summary of Research Findings

The researcher performed all the necessary black, white box tests and performance tests using the confusion matrix, the author found that the system had satisfactory performance. The system was tested in average response time, accuracy and it achieved 1.05 seconds and 95% respectively.

4.6 Conclusion

Chapter 5: Conclusion and Recommendations

5.1 Introduction

This chapter brings the research to an end and takes a retrospective view to establish whether the objectives of the study were achieved. The chapter represents the summary of findings, conclusion drawn from the research and recommendations for further studies.

5.2Aims & Objectives Realization

The first objective of this study was to design and implement a changeover switch that uses a revers bi-directional relay to decide when to change the power supplier i.e. from a utility power supplier to a secondary/ localized power supplier. The second objective was to design and implement a notification module which monitors the state of the switch and send a notification if it detects an anomaly. The third and last objective was to assess the effectiveness of the use of a connected and intelligent/smart changeover switch in deciding whether to change from a primary source to a secondary source or vice versa.

Therefore, to this end, the researcher developed a changeover switch model that Arduino microcontrollers to detect power in a line and automatically switch to auxiliary power if power is cut which satisfies the second research objective.The model is also capable of communicating to the user of the person in charge automatically. The researcher performed all the necessary black, white box tests and performance tests using the confusion matrix, the author found that the system had satisfactory performance. The system was tested in average response time, accuracy and it achieved 1.05 seconds and 95% respectively. Therefore, providing an improvement over the results obtained by other researchers such as (Ezema et al., 2019) and (Boma & Ikwuagwu, 2021) The gained results are significant and confirm the efficiency of the use of connected and intelligent/smart changeover switch in deciding whether to change from a primary source to a secondary source or vice versa . This, therefore shows that the objectives mentioned in chapter 1 were achieved.

5.3 Major Conclusions Drawn

This work presents an IoT based models capable of producing accurate switches when compared with traditional strategies. It was found to be reliable when applied to stable power, provided there were no significant anomalies of the voltage. The error metrics here discussed support the evidence that the changeover switches made are similar to the real observation. The need for continuous and uninterrupted power supply to consumers has become one of the leading demands in Zimbabwe currently. In order to efficiently connect and supply power, efforts have been made to create and establish more power stations and substations so as to reach more consumers. With these projects in hand, the challenge to provide uninterrupted power is posed and therefore, the limitations that arise from the current conventional methods employed can be improved through this research. From the designed automatic changeover system for transformers, both high voltage and low voltage power stations can adopt this system depending on the nature of the loads required by the various sectors and consumers.

5.3 Recommendations & Future Work

This research focused mainly on power supply and therefore the results are important to power distribution and technological stakeholders in the energy industry for smart grid developments and designs. The assumption made in this study is that the transformers used in the stations are similar in terms of ratings. The assumption was adopted for the purpose of designing a quick automatic changeover system that did not require time lapse.

References

Ahmed, M. S, A.S.Mohammed “Development of a single phase Automatic Changeover Switch”, Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Nigeria. July, 2006

Oladokun (2013), “Design and Construction of an Automatic Mains and Phase Changer”.Book entitled by “Maintaining Mission Critical Systems in a 24/ Environment”, Publisher: Wiley-IEEE Press, Pages: 89 -111, Subject Categories: Power, Energy, & Industry Applications.

J. G. Kolo, “Design and Construction of a Single Phase Automatic Change-Over Switch”,DepartmentofElectrical and Computer Engineering, Federal University of Technology Minna, Nigeria, 2007.

R.Silva,“How automatic transfer switches work”,retrieved online from http://www.articlesbase.com/ tool_and_equipments. November, 2009

Agbetuyi, A. F., Adewale, A. A., Ogunluyi, J. O. & Ogunleye, D. S., 2010. Design and Construction of an Automatic Transfer Switch for a Single-Phase Power Generator. 192 Journal of Electrical Engineering, pages1-2

Osaretin C.A.; Ibhadode E.I.; Igbinovia S.O. (2016) Design and Implementation of Automatic Changeover Switch (With Step Loading) for Renewable Energy Systems. Int. J. Renew. Energ & Environ Vol.2, pp179-192