UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

University of Rwanda

Title of the Project:

DEVELOPMENT OF AN ARDUINO BASED PROGRAM TO HANDLE AUTOMATIC PHASE SELECTION FOR RELIABLE POWER DISTRIBUTION

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A dissertation submitted in partial fulfilment of the requirements for the degree of MASTERS OF SCIENCE IN ELECTRICAL POWER SYTEMS

In the College of Science and Technology - African Center of Excellence in Energy studies for sustainable development (ACE-ESD)

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October; 2022
Kigali-Rwanda

Declaration

I declare that this Dissertation contains my own work except where specifically acknowledged, and it has been passed through the anti-plagiarism system and found to be compliant and this is the approved final version of the thesis.

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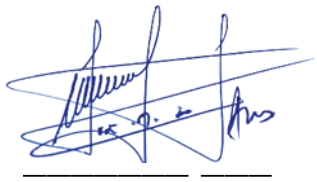
Date: October 30th, 2022

Approval

This Dissertation has been submitted for examination with my approval as a university advisor.



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Thesis Advisor

Signature

ABSTRACT

The aim of this research was to develop and implement an automatic phase selector that will be used to provide a reliable power supply to the load in distribution system. It explains why the selection of a good power quality phase (live wire) among the 3 phases in distribution system using Arduino is preferable than employing a manual phase selection in case of a power failure especially when one phase (live wire) is missing. This thesis had revised the previous studies done on phase selection system and suggested the areas of improvement.

Both voltage transformers, relays, diodes, Arduino and GSM have been used for the implementation of this project. This device will be used for single phase load; the 3 phases will be fed to this device and Arduino will compare the voltage of every phase so that the good phase will be supplied to the load when one phase is missing the supply authority will be informed via SMS. As an expected result when one phase failed another good power quality phase will be automatically selected and fed the load without any notice of phase failure to the load. To solve the effect of phase failure problem in power systems, this research suggested a powerful Arduino based program using c programming to handle the problem.

For the selection of phases, the implemented circuit first check voltage range of each phase that is 207V minimum if the voltage is within the range the corresponding LED is ON showing that this phase is ready to supply the Load unless the LED is OFF. The highest phase voltage is only allowed to supply the load when the allowed phase is overloaded, the circuit compare the inputs voltage and select another phase that supply the load. If also the selected phase is missing the circuit again select another good phase to supply the load. Experiment shows that the indicator(LEDs) are on only if the corresponding phase voltage is within the accepted voltage rage for example if voltage on phase R is 216.21V, voltage on phase Y is 209.84V and Phase on voltage 201.05V; only Red and Yellow LEDs are ON while blue LED is Off. Also experiment shows that the allowed voltage range phase supplies the load for example if Voltage on phase R is 196.66V, voltage on phase Y is 209.84V and voltage on phase B is 201.05V the load is supplied by phase Yellow. If all phases are within the range the circuit selects the highest phase voltage to supply the load for example if voltage on phase R is 210V, voltage on phase Y is 215V and Voltage on phase B is 220V the Blue phase selected to supply the load.

But for avoiding switching of relays many times, the phase greater than other phases atleast volts above 3V will be allowed to supply the load. For example, if phase R is 214 V, phase Y is 203.91V and B is 218.41V the load is supplied by Phase B. But for example if phase R becomes 219.95V even if this voltage is greater than phase B, for avoiding switching ON and OFF relays many times the phase B continue to supply the load. And if the allowed phase is missing another phase is automatically selected to supply the load.

List of Acronyms and Abbreviations

a.c.	alternating current
DCs	Developing Countries
EUCL	Energy Utility Corporation Limited
HV	High Voltage
IC	Integrated circuit
IDE	Integrated Development Environment
LHS	Left-hand Side
LCD	Liquid Crystal Display
LV	Low Voltage
RHS	Right-hand Side
REG	Rwanda Energy Group
3PPS	Three-phase Power Supply
IDE	Integrated development environment
GSM	Global system for mobile Communication

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CHAPTER 1

INTRODUCTION

1.0 The Research Background

The purposes of electricity dispatch/distribution systems are to supply the power in an uninterruptible continuous way, at high efficiency and with high reliability while responding to the power demand with an adequate safety margin. However, this target is hardly achieved in most developing countries (DCs) that are marked by never-ending failures, highly unreliable supply due to the unbalance of the standard 3-phase power supply and a quality degradation issued by power variations[1]. This eventually leads to damage and deterioration of electrical equipment and indirectly affects the economic growth of the country.

In Rwandan distribution system, the technician from the electricity utility company connects the new customer to the phase randomly. Since one phase is inherently prone to overload, an automatic phase selection circuit is a corrective solution. This circuit protects the customer from being connected to the overloaded phase, which helps to balance the loads in 3 phase distribution network. As a result, the effect of unbalanced load, such as power loss in the system, cables overheating, change of profile and magnitude of voltage; get reduced[2].

If a phase is missing or it is not within the range of accepted voltage, the automatic phase selector will select another phase that can supply the client. Automatic phase selector using Arduino is a circuit that compares three phase voltages and switch one phase to the load. The circuit contain mains parts that are: Analog reading part using signals from step down transformer, Arduino that compares inputs and switching units using relays. Transformer is used to reduce the input voltage of the supply from 220V to 8V for sensing purposes. The reduced voltage is rectified using bridge rectifier. Arduino checks all phases and select the good phase by providing 5V Dc to the corresponding relay for energization purposes, then the selected phase supplies the load. As a single phase energy meter is supplied by single phase line, if there is a fault on a single phase the energy meter will be totally disconnected to the national grid until someone comes and connect the energy meter to the available phase. But at that moment of waiting technician there is a possibility of losing life especially in hospitals. So it is necessary to use automatic phase selector to provide reliable power supply especially in case of one phase failure.

1.1 Problem Statement

As basically observed in most DCs, the phase selection is manually operated within the Three-phase Power Supply (3PPS) systems; which often give rise to imposed power flow interruptions. Moreover, the outgrowth can be the unbalanced load that consists in the pertinent issues of DCs.

Other reasons that can cause loads unbalancing in a 3-phase distribution line are:

- Single phase overloading
- Random loads connection on a 3-phase distribution network
- Initially unbalanced load in 3 phase distribution network.

Due to the above challenges of todays' network; some clients still experience (i) under voltage, (ii) power cut-off in peak hours, (iii) even supply utility get faced with technical losses in the network due to the unbalanced load and (iv) different loads on customer side succumbs from sub-standard power supply. This calls for the automation development of a phase selector to enhance reliability, power quality and operation convenience.

1.2 Objectives

1.2.1 Main Objective

In view of the aforementioned challenges, this work aims at designing and developing an automatic phase selector that can connect the load to a phase of good power quality among the 3 phases available in the distribution network; in order to guarantee uninterruptible and reliable supply of electricity.

1.2.2 Specific Objectives

Specific goals include:

i) Develop an automatic phase selector that is efficient enough for use in a three-phase distribution system
ii) provide a constant power supply that can meet the load
iii) To avoid risk of doing manual switch
iv) To have a quick selection of phase when One failed due to a power Issues
v) Program the Arduino to provide a stable power supply
vi) Inform the supply when phase is missing for quick intervention
vii) To implement a prototype phase selector.

1.3 Research Questions

A good number of questions have guided the problem identification and decision making to opt for this research focus.

i) What can be done to provide a reliable power supply in three phase distribution network?
ii) How can be done to eliminate the risk of using manual switching system?
iii) What can be done to supply the load with a good power quality phase?
iv) What can be done when one phase missing in 3 phase distribution li
v) How power losses within 3-phase distribution networks can be reduced?
vi) How the voltage drops, especially during peak hours, can be reduced?
vii) What can be done to reduce the time it takes to switch the phase manually?

1.4 Justification

This project is very important for phase selection because it aids for providing the reliable power supply to the load in case of power failure and eliminate the time taken to change the phase when one failed also it will eliminate the risk of being electrocuted when manual method of phase selection is used.

1.5 Scope of the study

Due to the limitation of time and budget, this circuit will be limited to the use of other sources of electricity such as generators, which can be used as backup when all phases are failed or there is power cut-off. The simulation will be done using proteus. When the phase is missing, it will be possible to inform the supply company.

1.6: Contribution

This project helps the single load clients to be continuously supplied even if one phase is missing in Distribution line. The implemented project also helps the clients to be supplied by good selected phase referring to the allowed voltage range. It can be also used as a secondary protection because it can't allow phase below standard voltage range to supply the load. This circuit helps the utility to reduce the effect of unbalanced load in distribution system. This project provides reliable power supply in distribution system.

1.7 Thesis Organization

This thesis has five chapters: Chapter one is the introduction, Chapter Two is the Literature Review, Chapter three is the methodology, chapter four result and analysis last but not least is chapter five which is conclusion and recommendation. This thesis also has references and annexes.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter discusses the meaning of an automatic phase selector, its typical usefulness and applications. In order to construct a fully operative automatic phase selector, some important material components will be narrated. This chapter also discusses the effect of power failure for systems using manual change of phases, and power system instability for systems using automatic phase selector. Finally, previous research works, as conducted by other researchers, will be discussed, as well as the remaining research gaps needing further research efforts.

2.1 Basic Concepts

Power failure is a common issue of power systems. Using backup options like solar power and electric generators is one of the available alternatives to that problem. Some researchers have shown that more than 70% of distribution network interruptions are issued by a defective single phase while the other 2 phases stay intact. Thus, a phase selector endowed with operational automation is a convenient preventive countermeasure for 3PPS systems[3].

Nowadays, the electric load demand is increasing while the development of generation and transmission infrastructures does not adapt accordingly. More importantly, the abundance of supplied services of massive electrical load, such as hospitals and industries, changes the power quality, especially when there is a sudden increase in the power load. When the increased load cannot be satisfied by the main electric grid, other sources such as solar power and electric generators, can be used as backup recourse. If all sources are available, an android system can be used to select a befitting source, with the ability to provide the electricity to the load without harm. Using Android app in the case of sudden load increase, one or two backup sources can be used to meet the load requirement. On other hand, an overload protector may be used to prevent the current from exceeding normal ratings. If such situation emerges, the last load gets automatically disconnected from the circuit [4]. It is good to note that phase failure causes the reduction on revenues especially for business and cause darkness to the residential houses especially during the night. So there is a need of providing the solution to this problem. By using Automatic phase selector, if one phase failed another phase can be selected.

2.1.1 Effect of Power Failure

Today's industry always uses appliances that require 3PPS. Therefore, even a single failure can lead to an immediate shutdown of various machines. An embedded circuit that can accept one phase among the supplied

3 phases can be used. As of nowadays, electronic circuits bring great and important changes in our everyday lives, as electric energy has become one of fundamental needs of human kind here on earth. Due to different factors, including the environmental conditions and other sporadic failures, electricity cannot be continuously supplied in DCs. Therefore, different circuits can be designed to allow machines, like 3 phase motors, to be supplied even if there is one phase missing.

Another remedy has been to create 3 phase from the only one available phase in the 3 phases supply using automatic phase selector circuit, then that single phase can be converted to 3 phase using a converter circuit [5]. The 2 phase Low voltage out of the supplied 3 phases is also possible. However, in case there is a need to proceed with the equipment supply, a used method may be selecting the available phase in step 3 phase network**.** Since long ago, phases used to be changed manually. However, in this 21st century, digital automation is quickly evolving, thus being used in most of engineering applications. In order to reduce the impact of frequent electricity cuts, the human intervention, especially in phase changing should be reduced. This can be achieved using microcontrollers. The microcontroller-based phase switching can be used in hospitals, pharmaceutical industries, etc.[6].

In a 3-phase network, there is a three-phase generating coil that can be connected in either a star or delta configuration. There is a displacement of 120° between each phase for the ease of transmitting and distributing power. This method is often used, and it is popular in home lighting, industrialization, commercial building etc. Phase disposition steps the voltage up and down at a given time in a generating coil. In single phase line, there is one live wire and return wire named neutral wire. In three phases; when one phase is overloaded, there is a reduction of voltage in that wire and overload can cause overheating in the wire.

Different faults can cause one or two phases to be missed, and different electricity-driven appliances end up not being supplied as a result. Advanced technology can be used to avoid this issue by designing and implementing a phase selector circuit. The expectation is to have a device that can be able to select on optimal phase among the 3 phase within milliseconds in order to continue supply the loads [6].

2.1.2 Manual Changing of Phases

Due to power instability issue in many DCs, the need of automation in electrical Power generation is desperately needed as power outages increase. As the process in industrial and commercial buildings depend on electricity, there are time-related problems if the process of changing phases is manual.

Manual changing of phases can cause electrical machines to be damaged due to human error, and humans can be electrocuted. An embedded circuit can be used as a solution, where the availability of phases is

monitored and the optimal phase is automatically selected. The automation of phase selection can be achieved by using relays, making sure that at least one relay is energized and always supplies the load. In case all phases failed, a mechanism of switching the load to the generator can be designed. Power interruptions affect both public and private services as there are services that need constant electricity supply like hospitals, banks, and pharmaceutical industries [7].

As manual switching can cause serious problem in the above mentioned examples the phase selector circuit can be an integral part that can help to switch the normal phase to the load automatically [8]. Imagine cases like doctors performing life-saving operations in hospitals, bankers transferring money between banks. Phase missing-based failure can lead to substantially dangerous losses. On a wider scope, constant power failures can substantially challenge the development rate of a country. Therefore, many developed countries have progressively eliminated the use of human intervention in phase switching, which in turn considerably reduced the formerly endured delay, leading to optimized power system operations [9].

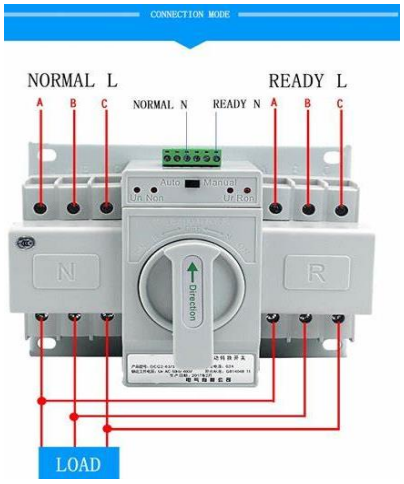


Figure 2. 1: Manual change switch

2.1.3 Power System Instability

Power outages leads to different sensitive elements being kept without functioning. Those sensitive devices can be easily damaged if the power keeps the on/off alternation, otherwise referred to as power system instability. In DCs, power generation is insufficient to the consumers and Power lines are overloaded, resulting in the power trip by the aid of switchgears. Power authorities in developing countries proceed by load shading, which affects the loads operating from the main supply.

As we know electricity play an important role in the economy of the country but its supply it's a big issue. When many industries increased and urbanization increased at high rate; this cause power system instability, many industries suffering from economic lost and affect revenues. most of the time the supplied voltage is

low even at a rate of not starting a machine as the result the user spent a lot of money to cover the effect of power instability [10].

2.1.4 System Using Automatic Phase Selector

In power system when backup is required it is of great important to use automation to reduce the power instability effect. When the load is single phase, the automatic phase selector can be used to switch the available phase to the load. In the automatic phase selector, relays are used as the switching and primary protection devices. Those relays can be electronically or electromechanically they can respond to electrical quantities like voltage and current for their operation like opening and closing of the circuit.

As power can be failed periodically and one or two phases missing the use of automatic phase selector device is one of the solution because it can faster switch the available phase to the consumer [11]. During phase failure the automatic phase selector and power factor improvement can be designed to switch the available phase to the load. Power factor can be improved to increase the efficiency when the power factor falls below the rated value. As we know the inductive load is the main cause of the bad power factor it is recommended to improve the power factor and this can be done using bank of capacitors [12]. Due to power failure injection of alternative means of energy for backing up the main supply can be used as alternative way. Coming of renewable energy sources bring a challenge of switching the load to the available source. As an integral part the automatic phase selector automatically switches the load to the available phase or source directly without delay [13].

However, for the selection of any phase at a particular moment if it is not done professional it can cause an outage. A microcontroller-based circuit thus eliminates these problems. This circuit it is an efficient design that safely select a best phase refers to the programmed language. This selection is made in milliseconds to avoid power loss. Best remote relay performance is only achieved by choosing a good phase to use as the polarized signal [14]. For the phase selection a magnitude based comparison method can be used. Single Phase failure can be caused by phase to earth fault (ground). Power issues arise from traditional phase selection methods [15]. Inverters connected to mains can cause power instability, so an automatic phase changer is required to protect the system. A sensitive phase selector can be implemented using microprocessor circuitry [16]. For fault clearance, it is necessary for the identification of the phase which is fault to be done correctly [17]. Traditional phase selector doesn’t adapt to power system dynamic however, an artificial based adaptive circuit can be introduced [18]. In that regard, for the selection of fault phase current waves can provide the needed information [19].

2.1.5 Electrical and electronics Component Used in Phase Selector

2.1.5.1 Transformer

Transformers are static equipment used to increase or decrease AC voltage with a corresponding decrease or increase in current. It consists of two windings wound on a common lamellar magnetic circuit. The primary winding (or primary) is connected to the source, while the load is connected the secondary winding (or secondary). Thus, as the voltage level changes, it passes alternating current from circuit to circuit without changing its frequency. An alternating voltage V1 is applied to the primary winding its value must be changed, depending on the number of turns of the primary (N_1) and secondary (N_2) variables.

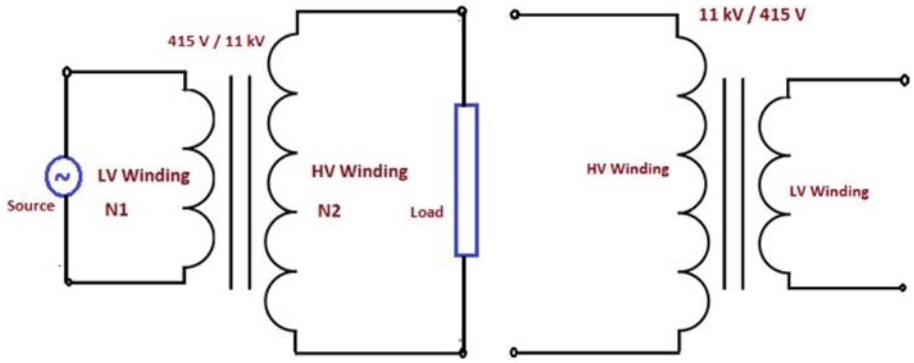


Figure 2. 2 Typical step-up transformer (LHS) and step-down transformer (RHS)

E_2 is induced in the secondary and E_2 in the secondary produces a secondary current I_2. So the load will have a terminal voltage V_2; If $V_2 > V_1$, it is called a step-up transformer. On the other hand, if the secondary voltage is less than the primary voltage the transformer is named step down transformer. Fig. 2.2 and Table 2.1 provide schematic and comparative distinctions, respectively.

Table 2. 1 A comparison between two distinct transformer designs

S/N.	Step-down transformer	Step-up transformer
1	The source voltage is greater than that of the output voltage.	The source voltage is lower than that of the output voltage.
2	The primary winding is the high voltage winding and the low voltage winding is the secondary winding.	The primary winding is the low voltage winding and the high voltage winding is the secondary winding.
3.	The primary voltage is greater than the secondary one.	The primary voltage is less than its secondary voltage.

4.	The number of secondary turns is less than the primary turns.	The number of secondary turns is greater than the primary winding.
5.	The primary current is less than the secondary current.	The primary current is more than the secondary current.
6.	This transformer type is used in power distribution. E.g. The one in a residential colony.	It is usually used in power transmission. E.g. The transformer of a generator in the power plant.

Figure 2. 3: Electronic transformer

2.1.5.2 Relay

Relays are used to open and close the circuit, either electronically or electromechanical. For this circuit Arduino was used to control the ON and OFF operation of the Relay. Both normally closed and normally open contacts are present in relay. For the working of relay, it needs to be energized this helps the normally open contact to be closed and also helps the normally closed contact to be opened. The metal core of the relay behaves as a magnet when a current pass through its coil, and this helps the contact to change its status. And relay contacts described as follow:

N.C: This is the normally closed contact when relay is not energized this contact allow the current to flow.

N.O: Normally open contact, becomes closed only if the relay coil is energized.

COM: Common contact, this can slide. If the lamp is connected to COM and NC contacts remains ON until the relay is energized.

The relay has the rated voltage, when this voltage is applied to the relay, the relay contacts change their status.

The usage relay during implementation can be energized by 5V Dc supply. Every relay has a limited current that can be allowed to pass through it. If the load can consume high current that can't can be allowed to pass

through the relay, this relay can be used to energize the contactor then the contacts of contactor be used to supply the load instead of connecting high ampere load directly to the relay contacts.

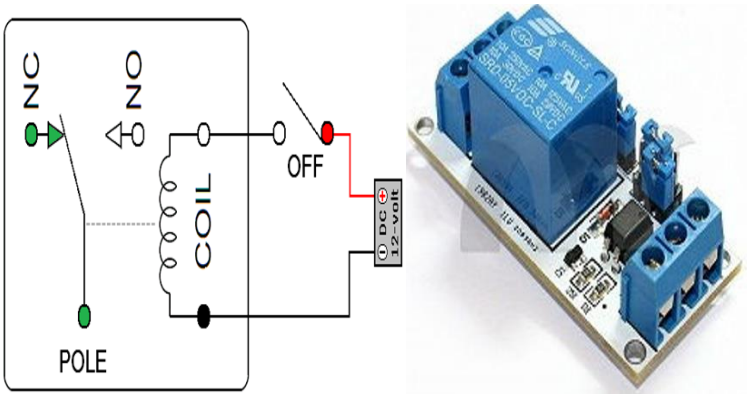


Figure 2. 4: Relay

2. 1. 5. 3 Switching unit

The switching unit composed by three relays in order to control the three lines supplied to the phase selector to allow one phase to be supplied to the load.

Mainly the neutral is directly connected to the load but the load needs both phase and neutral so the phase will be connected after checking all criteria that is the allowed phase must be within the allowed voltage range.

All relays are programmed in such a way that they can't be ON at the same time to avoid short-circuit, one relay must be ON when other relays are OFF. When relay becomes energized it allows selected phase to supply the load.

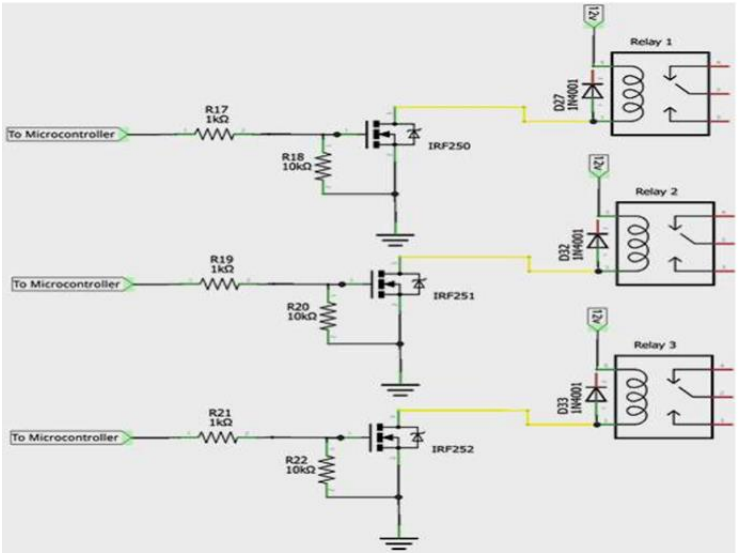


Figure 2. 5 Switching unit

2.1.5.4 Power supply unit

The power supply unit consists of the rectifiers, regulators, capacitors and three transformers for providing the power to the Arduino, the voltage from the supply is reduced using step down transformer. Bridge rectifier used to convert this AC input to DC then capacitor used to filter the DC voltage before fed to the Arduino sensing unit.

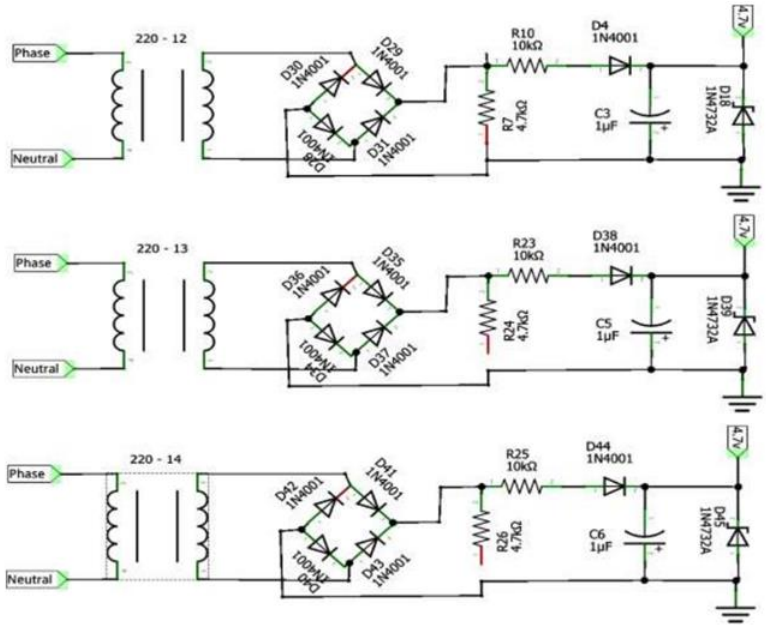


Figure 2. 6 Power supply unit

Transformer ratio can be calculated by means of Equation 2.1

$$\frac{ES}{EP} = \frac{NS}{NP} = \frac{IP}{IS} = \frac{VS}{VP} = K \qquad 2.1$$

Where; Es is the secondary electromotive force, Ep the primary electromotive force, Ns the secondary turns, Ep the primary turns, Ip the primary current, Is the secondary current, Vp the primary voltage, Vs the secondary voltage and K the turn ratio

The maximum voltage can be Calculated using equation 2.2

$$Vrms = \frac{Vmax}{\sqrt{2}} \qquad 2.2$$

Where; Vrms is the root mean square Voltage and Vmax represents the maximum voltage

Supply voltage to the Arduino board can obtained from Equation 2.3

$$V_2 = V_1\left(\frac{R_2}{R_1 + R_2}\right) \qquad 2.3$$

2.1.5.5 Arduino Board

Arduino uno main components can be shown in fig below, even if the Arduino Uno is not the first board to be released but it is the most popular board. Different tutorials on Arduino Uno can be found easily.

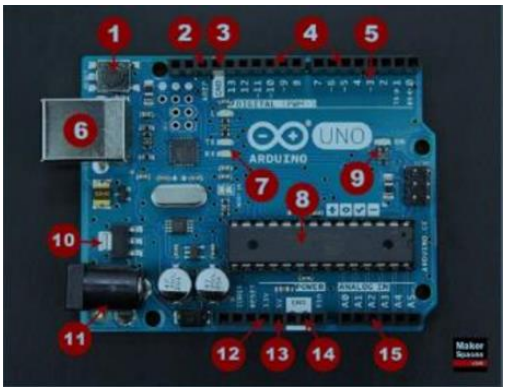


Figure 2. 7:Arduino Uno Board

Main components of Arduino Uno and their primary function are as follows:

- Reset Button (1): any loaded codes in Arduino board will be restarted by using this button
- Analog Reference (2): external reference voltage is set by this AREF;
- Mass Pin (3): There are a few grounding pins on the board which the same;
- Input/output digital signal (4): 0-13 pins are for digital signals either input or output;
- Pulse Wave Modulator (5): symbolized by (~) this is for simulation of analog output;
- USB Connection (6): codes are uploaded to the Arduino using this USB connection and also for supplying the board connected to the computer;
- TX/RX (7): Transmitter and receiver those port link the Arduino with GSM;
- ATmega Microcontroller (8): brain of board and is used to store the codes;
- Power LED Indicator (9): by applying power supply to the board this LED will be ON;
- Voltage Regulator (10): for controlling input voltage;
- DC Power Barrel Jack (11): Arduino power supply cable can be connected here;
- 3.3V Pin (12): this provided 3.3V to the project;
- 5V Pin (13): this provided 5V to the project;
- Ground Pins (14): Those are 0V pin to the board, and
- Analog Pins (15): those pins read analog signal then convert it to digital signals

Arduino boards can be supplied in three different ways:

• By our computer via the USB cable (5 V is provided)

• By a battery or a direct external Power Supply Unit (PSU) / Adapter

• By attaching a regulated 5 V to the +5 V pin

2.1.5.6 Current sensor

The current sensor recognizes the current in the wire and provide the information to that current whether it is low or high for the control purposes.

Figure 2. 8 Current sensor

2.1.5.7 Voltage sensor

Voltage sensor is used in the monitoring of the voltage level in each phase and give the signal to the Arduino board.

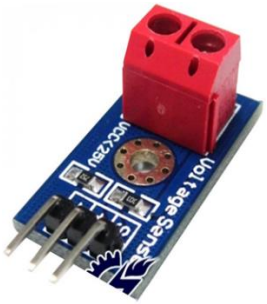


Figure 2. 9 Voltage sensor

2.1.5.8 Filter circuit

In order to reduce the ripples in the output of the bridge rectifier, the filter circuit is used. When there is no filter there can be a distortion of the signal and this implies the abnormal working of the circuit and relays can continuously vibrating even in the ON state. The filtering circuit contain a capacitor that charge in conducting half-cycle and be discharged in non-conducting mode. Also a capacitor opposes changes to voltage this helps to remove the ripples in the signal.

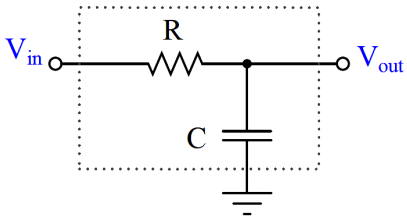


Figure 2. 10 Filter circuit

2.1.5.10 LCD

LCD stand for Liquid Crystal Display they are flat and light modulating properties of liquid crystals is used for their functioning. Between two sheets of polarizing element there is a liquid crystal solution that helps in the working.

Figure 2. 11: LCD

2.1.5.11: Potentiometer

Each electron passes through a conductor of the electricity closed network face with a resistance. Resistance opposes the flow movement of the charge. Movement of electron can be compared to the movement of water in water pipes. In electrical circuit the resistance to the flow of current can be compared to the friction that affect water flow in the pipes. The friction effect reduces the speed of moving water in water pipes. The same as water friction in water movement also there are some factors that affect the flow of current in the closed electrical network that make resistance to the flow of current to be high or low. Some factors like area, resistivity and length of the wire can affect the resistance.

Resistance at low temperature can't be the same as the resistance at high temperature but mainly

the cross section area of the conductor produces high effect on the conductor resistance that affect the flow of current on high majority. The material resistivity plays a big role in its resistance to the flow of current. The value of resistance can be easily calculated through color coding.

$$R = \rho \frac{L}{A} \qquad 2.4$$

Mainly, as material temperature decreases most conducting material decrease in its resistance to the flow of current and vice versa insulator resistance increase. But there are some materials that remain unchanged. There is what we call temperature coefficient of a resistance of a given material this can be described as the rate of an increase on the resistance of a 1 Ω resistor when there is an increase on the temperature by 1^{o}C.

$$R_\theta = R_0(1 + \alpha\theta) \qquad 2.5$$

There are some types of resistors that can control the voltage or current by providing high or low resistance to the flow of the current. As the resistance decreases in the potentiometer the current passing through the circuit increased and vice-versa. The potentiometer also used to vary the voltage using the voltage divider method. Incase voltage control is needed the variable resistor can be used.

Figure 2. 12: Variable resistor

2.1.5.12: Voltage Regulator

This is a 3-pin integrated circuit that provides 5V on its output. It has a pin for incoming DC voltage, grounding pin and the pin that provides 5V to its output. LM 7805 last digits shows that the output voltage of his regulator is 5V.

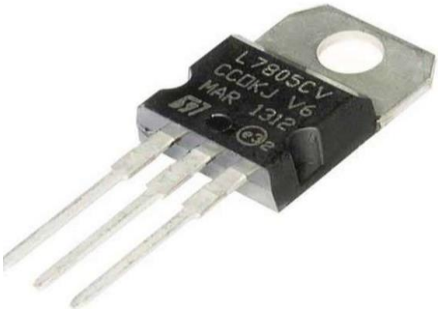


Figure 2. 13: Voltage regulator

2.1.5.13: Capacitor

It is hard to implement an electrical circuit without a capacitor due to its importance and some features that make it to be used. In power supply unit you can found there a capacitor as they are able to store energy. For controlling charging and discharging time capacitor can be used mainly in most integrated circuit like triple

5 timer. In power supply capacitors are used mainly for smoothing purposes. Capacitors are used in coupling system when a system has many stages combined together.

Capacitors are used for filtering circuit to remove unwanted signal in a given network. When you want to tune especially in radio system capacitors can be used. Storing system uses capacitors as they are able to store the charges. Capacitors are used in oscillation circuit, integrated circuit and power supply. Capacitors are used to remove ripples for better triggering of the circuits. Capacitors are used in speakers for providing loud volume as they store charges for quick release when needed. When relays or switches are opened some sparks occur then capacitors are used to reduce those sparks created.

$$C = \frac{Q}{v} \qquad 2.6$$

Where Q is the charge and V is the voltage

$$Q = It \qquad 2.7$$

Capacitor voltage is proportional to the stored charge this helps capacitor to be used mainly in op- amps. Capacitor circuit produce frequency dependent characteristics. Capacitors are used in both electrical and electronics circuits.

Figure 2. 14: Capacitor

2.1.6 Balanced load

In balanced load the power, voltage and current in all phases are equal this read to zero current in neutral wire but for unbalanced load the neutral current is different to zero and the voltage for each phase is not the same.

$$V_R = \sqrt{2}v_m \cos(wt + \theta) \qquad 2.8$$

$$V_R = \sqrt{2}v_m \cos(wt + \theta - 120) \qquad 2.9$$

$$V_R = \sqrt{2}v_m \cos(wt + \theta - 240) \qquad 2.10$$

$$I_N = I_R + I_y + I_B = 0A \qquad 2.11$$

For unbalanced load, the neutral current is different to zero

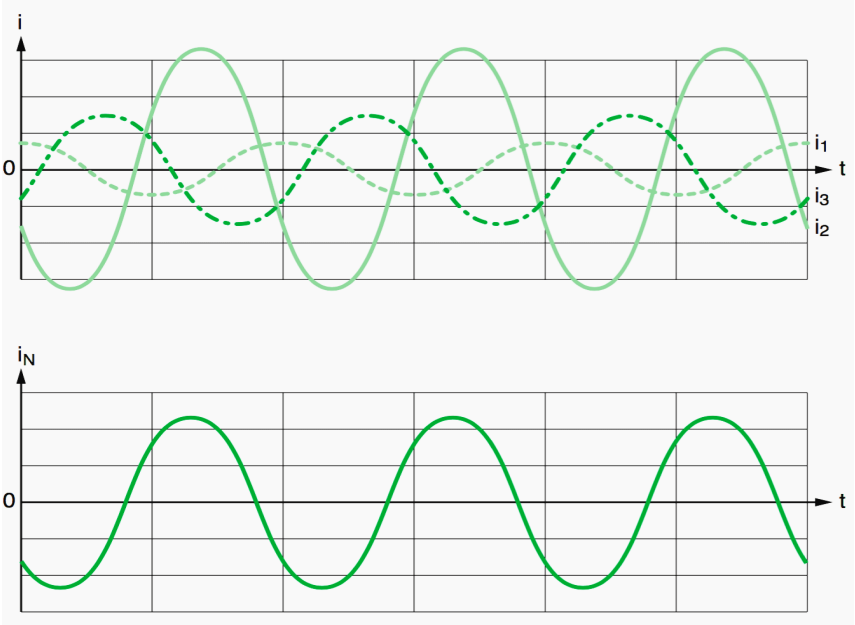


Figure 2. 15: Unbalanced Load

2.1.7 Alternating Voltage

One of the difference between alternating current and direct current is that in alternating current electric charges changes direction periodically but on DC it is only one direction. In generating stations electricity is produced mainly by proving mechanical energy that can be used to rotate the generator that are built using winding coils inside the stator. The generated voltage is considered to be rotating as also the magnets rotates. The transmitted energy is in the form of alternating current than direct current. Because the alternating current can be easily transmitted and distributed to final consumers by the help of power and distribution lines after transforming the alternating voltage to a high or low level according to the necessity. The generated voltage is transformed to a high level value before transmitted for the purposes of reducing the transmitted current to reduce the power lost in transmission line as generating station are so far from the main consumers located in cities.

$$P = I^2R \qquad 2.12$$

The received voltage at home is an alternating voltage. Lamps television and radios operate to source of 220V- 240V. unless the equipment's that can directly supplied by alternating voltage other equipment's like computers they have a power cables that convert incoming alternating source to Direct current source. For providing the source that can meet the internal electronics circuit needs. The conversation process can be done by first transforming the incoming alternative voltage say example 230V AC to a lower level say example 12V AC. Then this 12V AC will be input to the rectifier circuit that convert alternating voltage to

direct voltage. Input voltage for alternating current is mainly a sinewave form but also other forms such as square wave form or triangular wave form exists. The frequency mainly it is 50HZ but also due to different design 60 Hz network exist.

$$v_R = v_s - IR \qquad 2.13$$

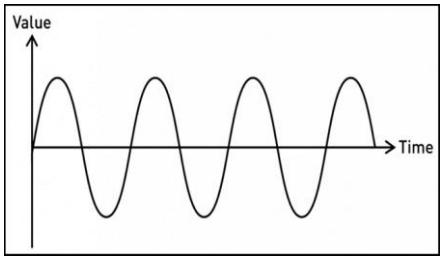


Figure 2. 16: input analog signal

2.1.8 Three Phase System

When a three phase rotating currents are used to supply the loads in distribution system that network is named as a 3-phase network. For transferring power from generating stations to substations, from substations to distribution area and also in distribution system three phase network is used. They are some loads that need three phase system in their operation like motors, water pumps and others. Even most residential houses supplied by single phase but they are some houses that need three phase network to supply their load like 3-phase washing machines.

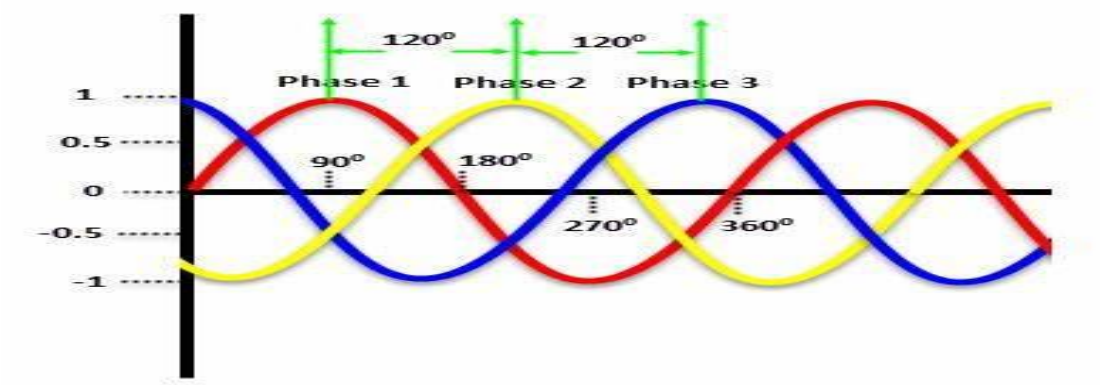


Figure 2. 17: Three Phase System

Three-phase system is economic compared with a single phase of the same voltage as it uses a less number of conductors. Three phases together provide a balanced load which can't be happened on a single phase system. Voltage in the three phases network changes from minimum to maximum constantly. Equipment that receive a three phase supply didn't experience the voltage variation. The three phase network is more efficient than single phase distribution network. The three phase motor consume less electricity compared to single phase motor of the same ratings and if the line is

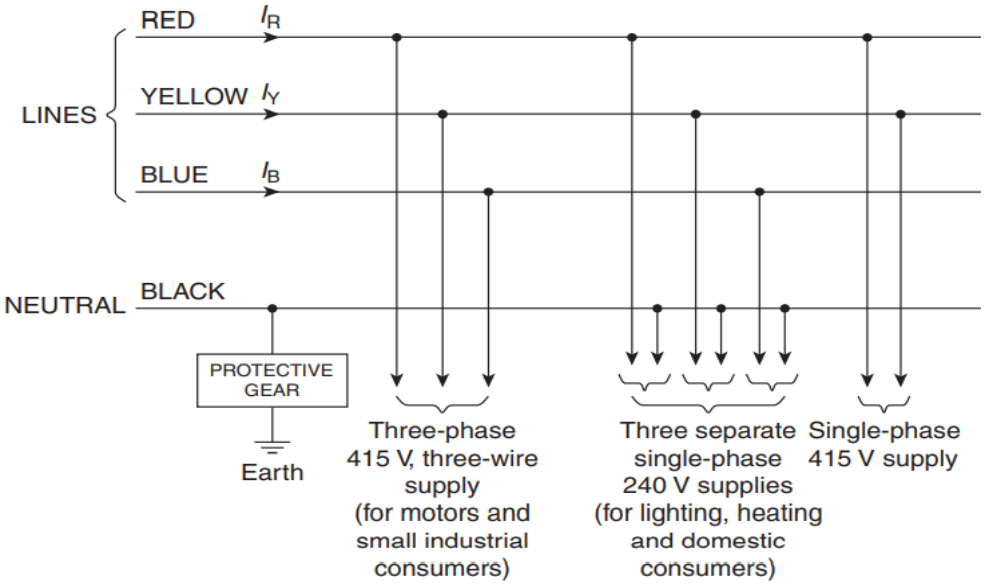


Figure 2. 18: Distribution network

2.1.9 Semi-Conductor

Semi-conductors are widely used nowadays, semi-conductors are used internally in microprocessors and in transistors. Most integrated circuits use semiconductors in their construction. Silicon are used to fabricate semi-conductors and most electronics devices are built up by semi-conductors. You can't construct transistors, solar panels and LED without the usage of semi-conductor materials. Controlled rectifier, integrated circuits even light dependent diodes are semi-conductor based electronic components. An example of a semi-conductor component is a diode. Diodes are used to conduct the current in only one direction this function helps diodes to be used in rectifiers and diodes are used to protect the equipment against overvoltage.

2.1.10 Full bridge rectifier

Full bridge rectifier is composed by 4 diodes connected in a square form so that input from AC supply is connected tom its opposite terminals. Load being connected to the other ends, then load will conduct the current during forward direction only and two diodes conducts together.

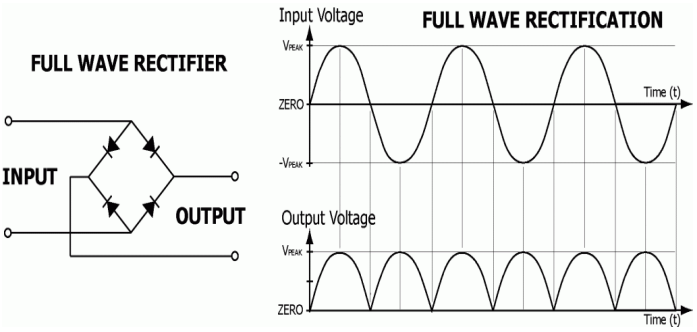


Figure 2. 19: Dc Voltage without capacitor

Even if the outputs from both half and full wave bridge rectifiers are DC but they are not good signal to be used as it is not pure DC. The output is not steady DC voltage like the output available for DC battery. Smoothing or filtering circuit helps to remove those unwanted signals from the half and full wave bridge rectifiers before applied to sensitive electronic circuit. For filtering a capacitor is connected in parallel with the load. This helps the circuit to provide output voltage which is near the peak value.

The output signal of a full wave bridge can be measured through its ripples factor this factor shows how the DC output signal is smooth. The ripples must be fewer in order to have a smooth output DC signal.

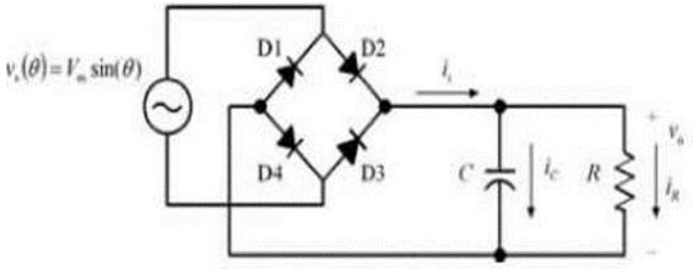


Figure 2. 20 Full rectifier with filter

$$Vdc = \frac{1}{\pi}\int_0^{\pi} VmSinwt\ dwt = Vm/\pi(-Cos\pi + Cos0) = 2Vm/\pi \qquad 2.\ 14$$

$$Vorms = \sqrt{\frac{1}{\pi}\int_0^{\pi} v_s^2(\mathrm{wt})\ \mathrm{dw\,t}} \quad = \sqrt{\frac{1}{\pi}\int_0^{\pi} (\mathrm{Vm\ Sinwt})^2\ \mathrm{dw\,t}} \qquad 2.\ 15$$

$$Vorms = \sqrt{\frac{\mathrm{Vm\^{}2}}{\pi}\int_0^{\pi} 1/2(\,1 - cos2wt)\ \mathrm{dw\,t}} \quad = \quad Vm/\sqrt{2} \qquad 2.\ 16$$

2.1.11 Variable load in distribution system

Final usage of energy can be a heating system or lighting system. Electrical energy nowadays, can be easily converted into another type of energy. That is why electrical energy has a best place among energy forms. Low price for electricity and reliable power source makes industry to be a profitable business. development of a country can be measured through its electricity consumption. Electrical energy is the best among other forms due to its easiest way of converting it into another forms, can be easily controlled, it is flexible, cheapness, cleanliness and has a high transmission efficiency. The aim of utility distribution is to supply many clients as possible but loads vary in accordance to customer wishes. Result of this is that load in distribution system can be never be constant it changes from time to time.

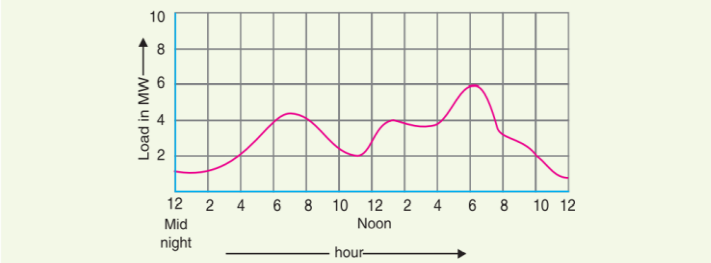


Figure 2. 21: Load Variation

2.1.12 Power Factor Improvement

The power factor is the ratio between active power and apparent power, however the power factor can be less due to the usage of induction motors, welding machines and power transformers. Huge amount of losses occurred in the power systems when low power factor produced in the power plants and substations. However, the power factor can be improved with a properly designed capacitors able to generate reactive power that will increase the power factor from a certain value to approximately unit value. Then this will reduce the angle between current and voltage from a certain value to the angle approximately to zero.

Mathematical calculations and electrical analysis is highly required in the correction or improvement of power factor and in this session. Bad power factor increases the loss in the transmission lines and produce heat in the cables and as load with low power factor consume high current. The improvement of power factor will save money and reduce the losses in the transmission lines as power losses in the transmission lines is square of the current.

The power factor can be improved by just connecting the designed value of capacitors called bank of capacitors in parallel to the load. This will reduce the reactive power of the inductive load result to low current drawn by load then as energy(kwh) consumed by load depend on the current as current reduced the energy will be reduced.

Energy efficiency and loss reduction is the main concern in the generation, transmission and distribution of electricity. However, some loads mainly inductive loads have a high reactive power result in losses due to high current, the power factor is the measure of the efficiency of the electricity usage. Correction of power factor results in the reduction of load current whereas low power factor results in the increase of the cost of consumed electrical energy.

Reactive power is the important parameter to consider in the power systems and when the reactive power is reduced the power factor increased and vice versa the reactive power is generated by two factors:

Reactive elements and unbalanced in three phase system and sensitive electronic devices are more disturbed by low power factor generated by unbalanced load. Different projects can be done to improve the power factor by connecting the capacitor in parallel to the load and see the effect of low power factor on the power losses and the money paid by clients on the electricity tariff.

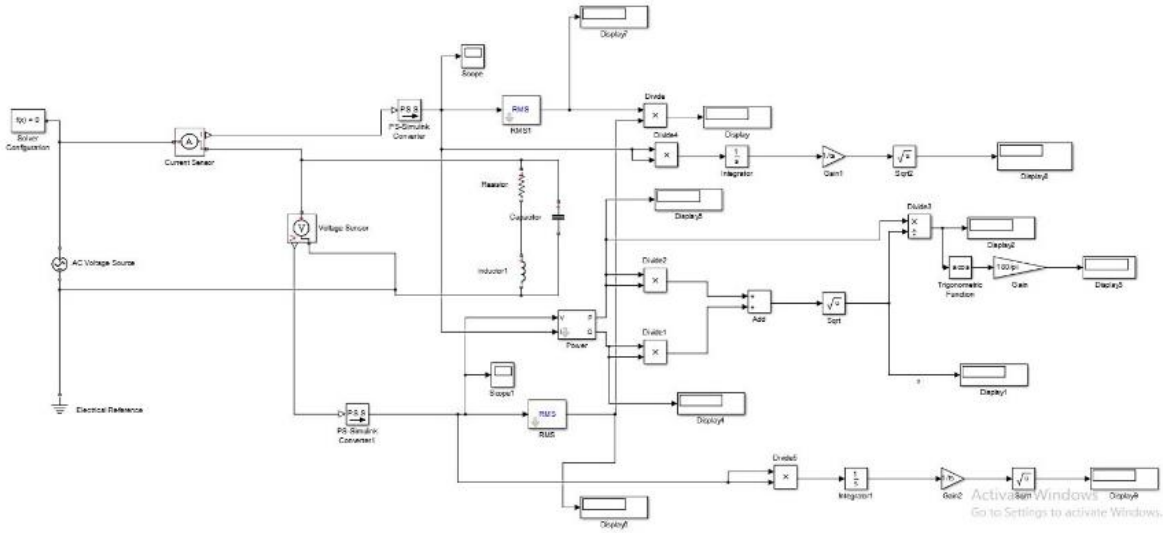


Figure 2. 22: Circuit with improved PF

Disadvantages of bad power factor can be listed, as the load drawn ampere is inversely proportional to the load power factor the bad power factor load consume high current and vice versa and high current load need high cross section area conductor

For single phase, Equations 2.17 and 2.18 apply,

$$P = v_L I_L \cos\theta \qquad 2.17$$

$$I_L = \frac{P}{v_L \cos\theta} \qquad 2.18$$

For three phase, Equations 2.19 and 2.20 apply,

$$P = \sqrt{3} v_L I_2 C \cos\theta \qquad 2.19$$

$$I_L = \frac{p}{\sqrt{3} v_L \cos\theta} \qquad 2.20$$

Bad power factor load has high apparent power as couched within Equations 2.21 and 2.22.

$$P = s \cos\theta \qquad 2.21$$

$$S = \frac{P}{\cos\theta} \qquad 2.22$$

2.1.13 Power System

Generated energy is produced at the generation station then transmitted in transmission line up to substations before feds the loads. The energy is served to the consumer as part of distribution system. Transmitted energy is at high voltage whereas distributed energy is at low voltage. Mainly there is a long distance between generation area and high load area. Distribution system is the part of the network that distribute power to the utilization. In between substation supplied by transmission line and consumers there is a distribution system. For better operation of clients loads the supplied power must be constant in potential, must be reliable, must be balanced, with high efficiency level and must be sinusoidal without interference.

For voltage regulation, as the load varies it is difficult to get a good operation of machines and lighting equipment when the supplied voltage is not within the accepted voltage range. The low and high input voltage to the motors affect motors efficiency. If the voltage is reduced or increased above the rated value protection system can trip and this led to power interruption. Task for utility company is to provides a reliable power supply but when power failed the loss business company face is high than the electricity that can be consumed.

Power failure can cause immediate effect especially in hospitals. So it is a task to the service provider to maintain an uninterruptable power source. Also it is important for the power utility to provide a balanced voltage in three phase system. Unbalanced three phase system supplied to motors produce the low efficiency on motors operation. And this lead to the output power reduction to the machines unbalanced voltage can cause motors to be overheated.

It is better to improve the power factor of the system to have an efficiency transmission line. There is a power factor penalty for consumer who has a bad power factor. Bad power factor produces high voltage drops in transmission lines. The power system must have a constant frequency that is because a system frequency influences the machines operation including its speed. And this speed must be constant to produce the uniform operation during the production in industry. Poser system must be protected in order to avoid the interference that can cause the abnormal operation of communication lines.

In electrical network we have what we call feeders this is the electrical line that connects the substations and the consumer. We have also a distributor this is the electrical line where are consumers are connected. The current in distribution system can’t be the same as different load are connected on different locations.

Finally, we have a service cable this is the cable that taps electricity to the distributor for the aim of connecting customer meter. Distribution system can be named according to the nature of current like AC or DC. Distribution system can be named according to the type of construction like overhead system or underground

system. Mainly generation, transmission, and distribution are done in AC form due to the easiest way of changing the magnitude of AC values using transformers either step down or step up. Transformers are used to increase the voltage before transmitting it for the purpose of reducing the transmitted current in order to reduce the losses in transmission line.

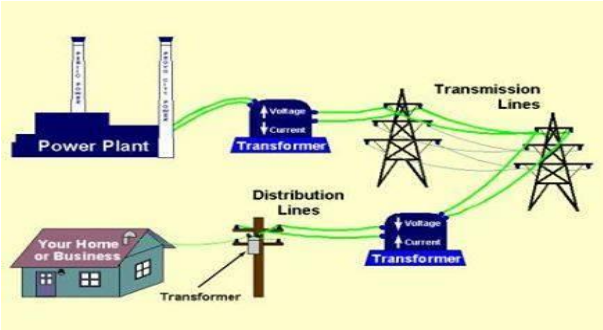


Figure 2. 23: Power System

2.1.14 Protection against Abnormal Voltage

In many cases load can experience either under-voltage or Over-voltage that means load can be supplied by voltage less or greater than the standard voltage. There are many causes of under-voltage or over-voltage in electrical lin. Overvoltage can be caused by switching, lightning, opening of protection device like circuit breaker. Under-voltage can be caused by overloaded a line some overvoltage signals may not be of a high value but may cause the damage to the load. Over-voltage may cause insulation to be damaged. There is always a need of dealing with abnormal voltage for proper operation of the materials connected in the line.

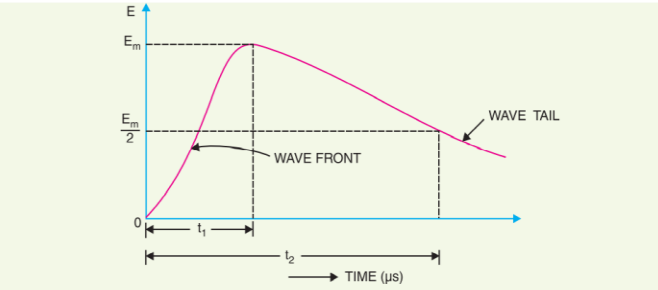


Figure 2. 24: Voltage Surge

2.2 Review of Previous Research on Phase Selector

In this section, we are going to recognize the previous research done Phase selector, appreciate their findings and identify the gaps to be addressed

Ofualagba, et al. 2017 [20] provided the way of changing phases from one to another when one or two failed, using phase selector and changeover switch for 3 phase supply.

For providing a continuity power especially during the line failure there is a need of using automatic phase selector to ensure the safest working of the electrical materials. Automatic phase selector can be used in industries, business buildings and residential houses for lighting, water pumping, house heating system and supplying computers. As a way of quickly selecting the good phase becomes a big issue, the use of automated circuit can be the answer. The use of logic controller helps to provide the selection of a good phase among the supplied phases. The system contains voltage sensing unit, processing unit, LCD unit, switching and power source.

For this research work the transformer used was 240V to 12V then full wave rectifier used to provide the DC output wave form. They used an ATMEGA 28 as a processor unit for the sensing purposes. They used a power bank module to provide the stable power to the components used. This project reduces the power instability for single phase load.

This project switches to the next phase when one phase on the grid failed and provide the means of changing to the generator in case all phases from the national grid failed. However, this research didn't increase the automation of phase switch between grid phases or generator to provide the reliable power supply.

Kalyankoko, et al. 2021 [4] designed a circuit that automatically supply the load continuously by selecting either; solar, grid or Generator using Automatic phase selector and overload protection by use of GSM. This project provides the means of changing between grid, solar or generator by the usage of an android app.

Nowadays, the electricity need make pressure on the line that are constructed years back. This led to power failure that made more sensitive areas like hospitals to be in dark time. This project allow load to be supplied by either solar, grid and generator. This circuit provide the way of supplying the load with available source. The designed circuit helps to stabilize the power in case of under voltage. Automatic phase selector becomes a link between power inputs for the aim of maintaining stable power source to the load.

This circuit control the changes on solar source for quick intervention if its output becomes low. This circuit has a voltage stabilizer and it has a Bluetooth panel that link the app with a mobile telephone for the aim of controlling the load operation. Telephone voice can be transmitted with the help of GSM 900 A as a text. There is a current sensor that sense the current drawn by the load. The Arduino used as a brain of the circuit and for the operation of relays in general.

In case load can't be supplied by single source, this project can combine two or 3 sources at the same time. An autotransformer can be used to stabilize the output voltage to 220Vac, when the current exceeds the

normal rating this project has the ability to disconnect the last connected load. However, this research didn't switch to another phase in case of phase failure.

Owojori, et al.2021 [7] to achieve a phase selection during power failure, an automatic phase selector can be analyzed and be designed.

Lack of regular maintenance on the transmission line and distribution line in many developed counties led to power failure and need intervention of other renewable source to help the grid. This research presents the good way of switching the single phase load to another phase incase grid is available or switch the load to another source when the grid is completely off. For better switching the phases, the designed circuit uses microcontroller with the help of the other hardware devices combined together. The proteus used for simulation then the simulated circuit implemented using different electrical and electronics materials. The incoming lines are monitored for the aim of detecting whether they are off then the circuit select another phase or source that can supply the load in case of power outage.

This circuit has 5 sources that are: sources from the three phases incoming line, one from solar and another one from the generator. The circuit contain transistor driving method, controller and switching circuit. Both AC power and DC power sources are used.

This research brought the usage of alternative sources such as inverters and generator for the purpose of switching to the other source when power failed. However, this research didn't provide the way of switching to another phase when the voltage falls below the standard level.

Venna Bhat 2021 [21] as 70% of power failure caused by one phase missing, no need of power backup although a an auto-phase selector can be designed.

This research developed an automatic change over switch that can be used for 220V-240V load to provide uninterruptable power source to the load. However, the researcher didn't include the details on the usage of Arduino in the implementation of automatic phase selection.

Shubham, et al. 2020 [22] for switching the load to the cheapest electricity power source, an automatic cost effective phase selector system is required. The economic growth of the country can be maintained by providing a stable power supply at a low cost. For providing the continuous source all renewable sources and grid connected system can be used. For providing a low cost switching method an automatic phase selector can be designed for the aim of making a solar source as priority then followed by the next cheapest source. This circuit uses different electrical and electronics component.

The use of logic devices makes the circuit to be easily selective to the source. In developed countries the high population leads to the overloading of lines then cause the power cut in some parts of the network. For the aim of backing national grid the need of producing electricity using renewable sources is preferable. When selection of phase is necessary, the manual selection of phases or sources waste the time and can make the un-normal operation of different apparatus used in the installation. Revenue loss can occur in case of manual selection of phase and this reduce the speed of the countries growth.

Then the solution to the mentioned challenges is the use of automatic selection of phases or source in milliseconds. When load depend on source, this can lead to the loss of power when there is a fault in the line.

Unbalanced load can lead to power failure in the line. When all phases are on, the selection of phase is needed to ensure the continuity of power supply in case one phase is missing. Mostly single phase load experience the effect of power loss when the line is off. As more time can be taken to switch the phase in case of manually selection, there is a need of employing automatic phase selection in the network. In case of manual selection an operator needs to be available when it is the time to select the phase and this lead the human to be electrocuted. The main target is to provide the stable power source to the single phase appliances. Above 70% of faults are due to the one phase failure. When all phases are failed, an automatic phase selector selects another source to fed the load.

This research employed the use of step down transformer (220V to 12V), rectifier (bridge B20), capacitors(1000µf), op- amp (LM 358), transistor BC547 and relay. However, the researcher didn't provide the way of minimizing the time taken to switch the load to another phase.

Okundamiya, et al 2013 [23] to select the most stable phase that connect power to residential load a smart phase selector and changeover power switching system realized. This research focused on design of an intelligent switching system and phase changing for the supply of a single phase load.

Required voltage of the supply line can have a fluctuation of $\pm$5% and need to be reliable. A good system must also have line protection system including both over& under Voltage protection, thunder protection etc… In many developed countries power outage (unplanned outage) becomes a serious issue. The outage caused by faults in the line, lack of maintenance, falling of trees in the line etc… Poor planning in developed countries make transformers to be overloaded. Mostly one phase failed due to fault, it is difficult to always check whether one phase is missing in order to shift the load to the correct phase. More energy is required to change the switch to the next source in case the utility failed. The use of Automatic phase selector helps the

consumer to save money and time when it comes to phase switching. The usage of intelligence switch helps the phase selection to be faster.

Contactors are used to carry the high current load. The target of this research is to investigate the usage of intelligent circuit that can supply the load with another phase for residential consumers. This research used contactors, alarm and display unit with aid of a microcontroller. However, researcher didn't provide a system that supply the reliable power to the load.

Awunde, et al 2021 [1] developed the deisgn and development of phase selector to provide the supply of load during the power interruptions.

Load can't be functioned well when connected to the source which is not stable. But regular faults occur mostly in developed contries network. This circuit provides the way of producing uninterruptable power source. The results shows that when input signal to one or all phases are available there will be always the output that supply the load. Stable source becomes critical in developed counties. In developed countries effort is made to the hospitals but those hospitals need reliable power suppply.

As the demand increased in developed countries grid is overloaded. As phase selection mostly done manually, this make the load malfunction and cause power interruption. So there is a need of imploying automatic phase selector in the system. The aim of this project is to provide the uninterruptable source to the single phase load.In this research the relays are controlled by control logic to provide the supply to the load. However, there is a time delay betwen an input to the logic gate and the activation of relays.

Ayan, et al 2016 [3] this research showed that there is no need of buckup when 3 phases supplied when a laod is single phase. Power disturbance and phase missing it is the normal isue in distrubution network this reduce the commercial revenues. To avoid the losses caused by power failure the additianal sources can be used. But the time taken to switch the load to another phase during manually operation is high and it is not cost effective. As 70% of fault occur in distribution line is due to single failure while remaining phases are available, an automatic phase selector can be used to provide a reliable source in distribution system. In this case there is no need of using extra sources. Phase is selected within few seconds this reduce the time consumed during phase selection. The purposes of this project is to provide an automatic phase selector to be used in altermanting source ramge between 220V and 240V input voltage.

There are other circuits similary to this examples: single phase selector switch, two phases selector switch and three phases selector switch. But this design concern to single phase switch-over to be used only on 3-Phase network.

Table 2. 2 Summary of the Previous Research and their Gaps to be addressed

Refs	Phasor Selector Technology	Focused area	Application	Gaps to be addressed
[20]	- Multiplexers (Analog CD4052) - Microcontroller (AT 89C51) -Analog to digital converter(ADC0804)	Protection of load from phase failure	Power distribution system	Advanced technology (Arduino)
[4]	Android app GSM	Protection of load from source/ grid failure	Power distribution system	Line phase failure detection.
[7]	Microprocessor (ATMEGA 328)	Power quality	Single phase load	Informing the utility when one phase is missing
[21]	Multiplexers (Analog CD4052)	Economic system	Single phase output system	Load balancing
[22]	Voltage regulator (IC 7805), Op Amp comparator (LM 358) and Transistor (BC 547)	Cost effective	Where free source like solar can be found	Overall cost of the system
		Reliable power	Power distribution system	Fast switching to the next phase
[23]	Microcontroller 8052	Power quality	Residential consumer	Develop circuit that can be used for industrial application.
[1]	Control logic unit	Voltage quality	Power distribution system	- Calculate system cost. - Correction of power factor. -Use of advanced technology

Table 2.2 Cont…

Refs	Phasor Selector Technology	Focused area	Application	Gaps to be addressed
[3]	OP Amp(IC 741)	Uninterruptable power supply	Single phase load	Switch off the motor when all phases missing
Ref.	Phase Selector proposed Technology	Application	The gaps to be Application	Reference
The proposed Technology	Phase Selector based on Arduino with GSM	Power distribution system	- Advanced technology(Arduino) - Line phase failure detection. - Reduce switching time - Informing the utility when a phase is missing.	The proposed Technology

Different loads for hospitals, residential, businnes centers, offices etc.. are more dependent to national grid but national grid ca be failed due to faults. This make national grid to be unreliable source. When all phases are ON in three phase distribution network, automatic phase selector ca be used to select one phase that can supply the load when fault occur on another phase in order to provide a reliable power supply. As many load are single phase based, like in hospitals, hotels, schools sometimes those loads are not supplied due to single phase fault in line. This can be corrected by imploying automatic phase selectro in line.

There is no time consumption when circuit chnges from one phase to aonother and this research presented a real automatic phase selector. For the case of manual changing of phases the pre-paid meter stopped immediately when one phase failded. The change-over for this work consist of a conductor and a gear motor. However, motor continue to rotates when all phases are missing.

2.3 Problem Formulation

The main objective of this research proposal is to develop an automatic phase selector switch which will automatically connect the load to a live phase when the other one failure or when it has a fault. This problem leads us to have an objection function which is stated in equation (2.23): In order to have a continuous function f(x) of Output voltage to the Load some conditions must be satisfied as shown in equation 2.24 and 2.25

$$f(x) = \begin{cases} 1 \;\; if\; V_{R\,,Y,B}\; Min \leq V_{R,Y,B} Nominal \leq V_{R,Y,B} Max \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad if\; V_{R\,,Y,B} < V_{R\,,Y,B}\; Min\; 0r \\ \qquad\qquad\qquad\qquad\qquad\qquad\quad V_{R\,,Y,B} > \;\; V_{R,Y,B} Max \end{cases} \qquad 2.\,23$$

Subjected to the following constraint

$$V_{R\,,Y,B}(Source) > 0 \qquad 2.\,24$$

$$\mathrm{f_{R\,,Y,B}\,(Source) = f_{standard}} \qquad 2.\,25$$

Where; $V_{R\,,Y,B}$ is the supply voltage; $V_{R\,,Y,B}\; Min$ the minimum source voltage and $V_{R,Y,B} Max$ the maximum source voltage.

2.4 Conclusion

Reference is made to the previous researchers; some researchers did a good job on phase selection system. However, some gaps are present on their work in this chapter problem is formulated using mathematical equation and some conditions to be satisfied for getting continuous supply of voltage to the load are mentioned.

CHAPTER 3

METHODOLOGY

3.0 Introduction

The research proposed here is a hybrid research in which both qualitative and quantitative aspects of research are intertwined. It is a qualitative research, in that it will benefit from textual results data and background of related works for providing evidence-based conclusions.

For information gathering aiming at developing this device; an extensive literature review that has been previously articulating around the subject matter of this project has been perused; and different key publications have been sorted out.

The prototype will be developed (Implementing the project using different electrical and electronics materials like: Arduino, transformers, relays, rectifiers, voltage sensors and LCD display). The circuit will contain the following sections; the power supply: the supply is an a.c., the stepdown transformer (230V-12V) will be used to reduce the voltage level. As many electronic components supplied by DC, a rectifier circuit will be used to transform AC to DC.

Phase sensing unit: 3 phase sensors that detect the presence of L1, L2& L3 respectively will be used. To sense the voltage level, the stepdown transformer will be used and voltage divider method will be used to provide the voltage needed for sensors.

Control logic unit: this is the brain of the circuit, the active phase to be supplied to the load is identified and the active phase is displayed on the LCD and the corresponding LED emits the light. Microcontroller will finally send a signal to the relay to switch ON the corresponding phase to be supplied to the load. Switching circuit: switching will be done by relays; those relays they are interlocked for avoiding short-circuit.

Active Phase Indicator: Indicates the phase applied to the load and the display uses an LCD to show an amount of electricity such as a voltage level.

3.1 Previous Method Applied to The Problem

Ofualagba, et al. 2017 [20] Used in 1 of 4 analog multiplexers (CD4052), analog-to-digital converters (ADC0804),AT89C51 microcontrollers and relay switches. However, this technology is the old method it cannot provide a fast switching time and it is not editable.

Kalyankoko, 2021 et al. [4] Used the Android app to select the selected source, and when the amount of load requirements exceeds the amount that one source can handle, use the mobile app to onboard one of the remaining two sources . However, this technology cannot be used in area where there is no internet and it cannot select another phase when one failed.

Owojori, et al.2021 [7] used microprocessor(ATMEGA328) comparator circuit to compare the voltage between each grid component (ie, the red, yellow, blue phases) and the alternate power supply (i.e. the solar inverter and generator), across the power transistor driver. Select an available source for connecting the load by the aid of automatic relay circuit. However, this technology didn't provide a fast switching selector.

Venna Bhat 2021 [21] used multiplexers(Analog CD4052) by providing the idea of an uninterruptable power supply with single-phase load. With three-phase, each single-phase can fail, after which the power supply automatically switches from the available three-phase power supply to the next phase. However, this technology didn't mention the cost of the overall project

Shubham, et al. 2020 [22] used Op Amp comparator (LM 358) by comparing voltage inputs either grid, solar or diesel generator and by the aid of zener diode the output can be regulated. If the solar cannot provide a standard voltage the op amp can switch to the next source. However, this method cannot select any of the mains grid phase to supply the load.

Okundamiya, et al 2013 [23] used Microcontroller 8052, when a transistor get in conduction mode the coil will be energized and close its contact this will led to the switch of the live conductor either red, yellow or blue to supply the load. However, this technology didn't provide a system that supply the reliable power to the load.

Awunde, et al 2021 [1] used Control logic this monitors the on and off operation of a 3 phase supply and energize the relay when any of the phases is available. However, when one phase is missing this technology didn't provide the way of informing the utility for quick intervention.

Ayan, et al 2016 [3] used Op Amp(IC 741) when one phase is present, Op Amp provide low output but when live conductor is missing the output of Op Amp will be high. This signal will be input to the electromechanical relay as result its coil will be energized and change its connection and motor start to rotate. However, this method didn't provide the way of switching off the motor when all phases are missing.

Table 3. 1 Summary of previous Methods, their strengths and their Weaknesses

Refs	Method used	Strengths	Weakness
[20]	Microcontroller (AT 89C51)	• Low power consumption • Low cost • It has a flash memory	• Low speed • 8 bit microcontroller
[4]	Android app	• Easily control the load remotely	• Electronic interference • Internet failure can put all system down
[7]	Microprocessor(AT MEGA 328)	• High speed 10 times others conventional microcontrollers • Simple in its usage • No more additional components	• Low performance compare with more bit microcontrollers
[22]	Op Amp comparator (LM 358)	• No need of 2 supply circuit • Dual OP Amp • Compatible to all logic	• No expectation of producing the output voltage that is near the input voltage.
[23]	Microcontroller 8052	• Ability to accept larger programs	• Program execution can be slow
[1]	Control logic unit	• System design is more economical	• Time delay • No way of informing the utility
[3]	OP Amp(IC 741)	• High voltage gain	• Limited to high frequency applications

Ref.	Tool	Content
The proposed tool	Arduino based program	• Hopefully, the voltage level of source will be considered • Hopefully, the frequency of the voltage source will be considered • Hopefully, the load capacity (IL)will be considered • Hopefully, the operating time of switching for relay will be considered • Hopefully, the supply utility will be informed when phase is missing.

3.2 Proposed Methodology

After reviewing the methodology applied on the problem by past papers, the proposed methodology and its merits is going to be discussed. Different technology focused on providing reliable power supply in distribution system. However, they didn't provide the way of changing phases even in the case of under-voltage in milliseconds when one phase is missing also they did not provide the way of informing the service provider for quick intervention. That is why Arduino with GSM based technology is proposed to mitigate the gap found in last research works.

Arduino is an open-source platform for electronics prototyping that has made engineering electronics easier through their construction and programming. It has the ability to receive and forward the information to a variety of devices, together with the commanding internet. The hardware employed is named as Arduino Uno circuit board and Simplified C++ as its programming software[2, 3].

The Arduino Uno board is shown in fig 1 it is a microcontroller board. It has a 14 digital input/output pins (6 can be used as PWM outputs), 6 analog inputs, a 16MHZ quartz crystal, a USB connection, power jack and a rest button. Board contains everything needed to support a microcontroller. Power supply can be an AC to DC adapter or can be powered using computer via USB and microcontroller receive program (codes) by means of USB or web. In this circuit of Automatic phase selector, microcontroller will select a good phase to be supplied to the load [24]. Among hardware components, there are USB Plug, External Power Supply, Reset button, Microcontroller, Analog Pins (O-5), Digital I/O Pins, In-Circuit Programmer, Digital and analog Ground pins, Power Pins. Three main software part of the Arduino IDE are Command Area, text Area and message window area [25].

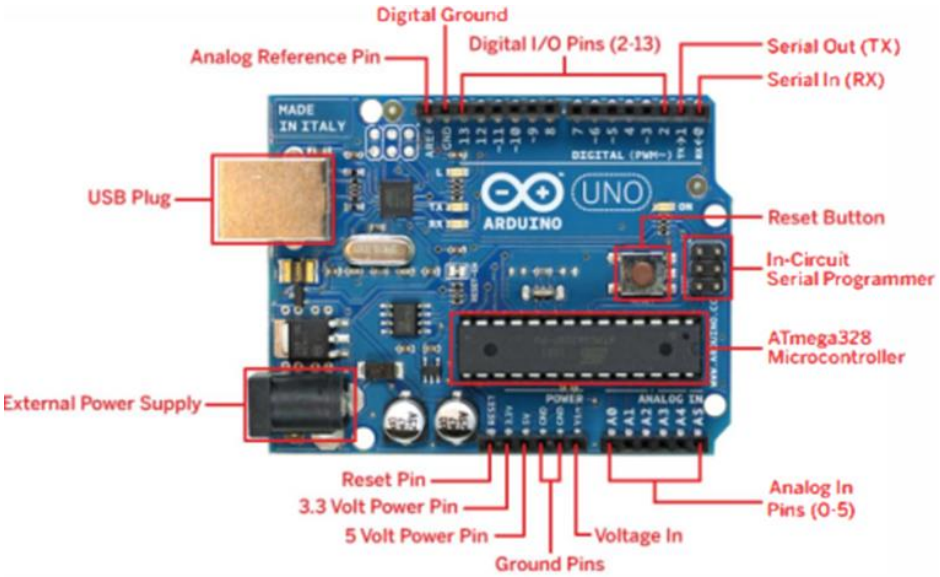


Figure 3. 1: Arduino-uno

The Arduino has been proven to be; an efficient tool for researches/studies [5], inexpensive, IDE can be used on every operating system, ready to use and has examples of codes. Down-to-earth applications specifically, it has registered plenty records in power systems, as well. Typically, Arduino has been employed in designing the AC power metering system by means of a multi-channel single-phase approach [26]. Similarly, the power metering function could be achieved wirelessly based on universal motor controller & light dimmer [27] Sonandkar, et al. could use the Arduino to measure the power while effectively responding to the demand, i.e. lessening household's energy consumption in the course of peak demand [28]. Durrani, et al. [29] have suggested a smart Arduino-based framework that can be used to distribute the power and balance the load; and, Barkat and Mahdad [30] Based Arduino-GSM, could develop an Experimental Educational Platform that is important in protecting the Power System.

3.2.1 Integrated Development Environment (IDE)

The IDE is a special program that runs on your computer and allows you to sketch your Arduino board in a simple language modeled after the processing language[31]. Press the button to upload the sketch to the board, and the magic happens. The code you write is translated into the C language (generally very difficult for beginners to use) and passed to the compiler. The leading open source software that makes the final translation into a language that the microcontroller understands. This last step is very important as it is place to make your life easier by allowing the Arduino to hide most of the complexity of microcontroller programing. The programming cycle of the Arduino is basically follows:

a) Connect the board to your computers port.
b) Draw a sketch that brings the board to life.
c) Upload this sketch to the board via a USB connection and wait a few seconds for the board to reboot.
d) The board is executing the sketch you wrote.

3.2.2 GSM (global system for mobile communication)

GSM stands for "Global System for Mobile Communication" and is defined as a digital cellular network widely used by mobile phone users in Europe and other parts of the world. GSM uses a variant of Time Division Multiple Access (TDMA) and is the most popular of the three digital radio telephone technologies (TDMA, GSM, and Code Division Multiple Access (CDMA). GSM digitizes and compresses data and sends it over the channel, along with two other user data streams, each in its own time slot it operates in the 900 MHz (MHz) to 1800 Mhz frequency band[4].

Figure 3. 2: GSM

The GSM is part of the evolution of wireless mobile communications, along with other technologies such as High Speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS), Enhanced Data GSM Environment (EDGE), and Universal Mobile. Telecommunications Service (UMTS).

3.3 Conceptual Framework

Figure 1 explains proposed research conceptual framework. It shows the order of ideas and how step by step the main objective of this project will be achieved. It will start by reviewing the existing technology of the phase selector this will followed by problem identification and problem design. Arduino will be programmed using c++ programming. This will be followed by implementing the selector the last but no least is the testing of the device and sensitivity analysis will be done.

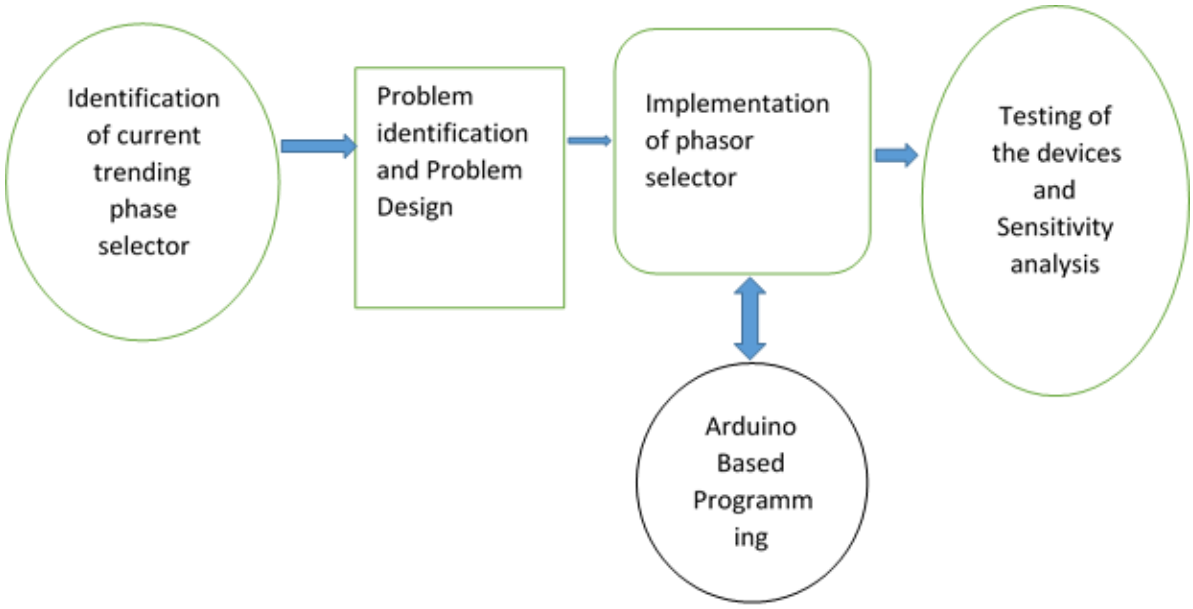


Figure 3. 3 Conceptual Framework

Flow chart

The flowchart in Fig. 3.1 portrays the algorithmic procedure to search for phase availability and select the good phase. This is the algorithm shows how the system will work, after initiating the system, the priority phase is phase R, the system will check whether this phase is active. If the phase R is active, this phase will supply the load. If phase R is missing the system will check the phase B. If this phase is active, it will be supplied to the load. If phase B is missing, the system will check phase C vice versa.

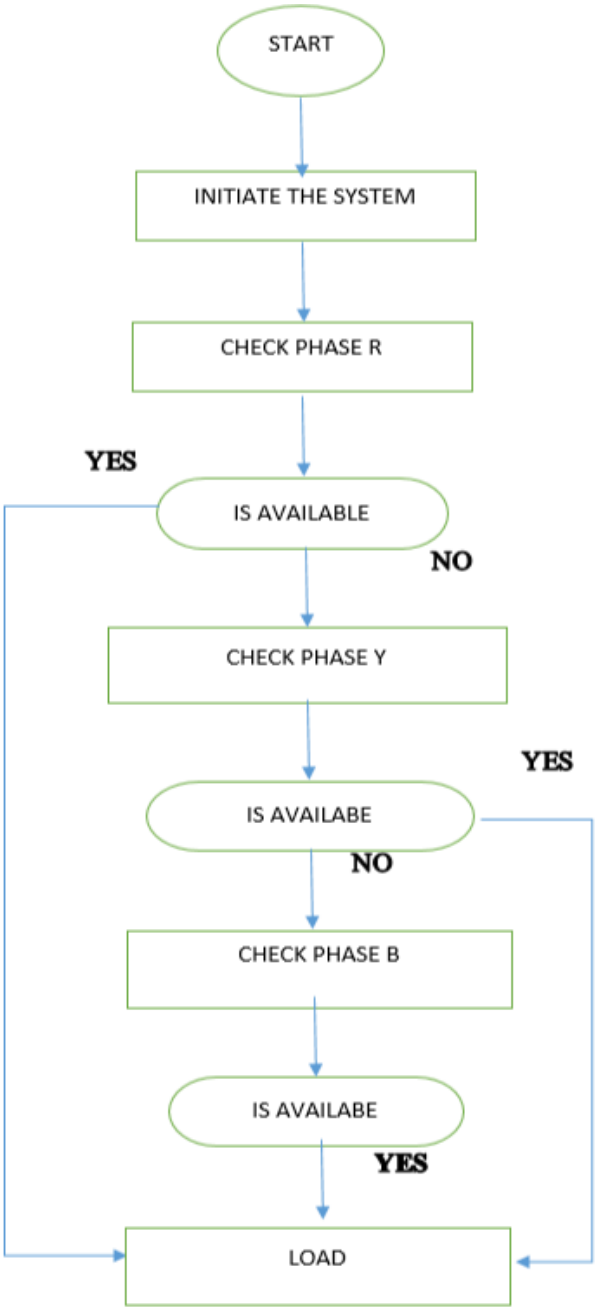


Figure 3. 4 Flow Chart of the Algorithm

3.3 Mapping methodology to the Problem

Arduino will be used to link the control logic circuit with the switching relays. By using USB a set of codes can be transferred to the Arduino. Those codes will be provided using IDE software, relays will be ON or OFF according to the instruction programmed.

The proposed circuit will check all three phases input then select the good phase to be supplied to the load. Arduino will make sure that if one phase is missig; without delay another phase would be supplied to the load to provide the reliable power supply, also by using GSM the message will be sent to the service provider to solve the issue.

Table 3. 2 Mapping Table

METHOD PARAMETERS	**Examples and its role in IDE program**
Integers data	Like Input voltage
Float data	Decimal numbers
Character data	Correspond to letters
While loop	Checking phases availability from phase R

3.4 Conclusion

In this chapter previous methods applied to the problem are discussed, their strength and weakness are summarized. In this chapter the proposed methodology is discussed and flow chart of the phase selection is discussed in order to select the good power quality phase that can be able to provide the reliable power supply to the load.

CHAPTER 4

IMPLEMENTATION AND RESULTS

4.1: Introduction

Analog inputs (Voltage) are sensed by transforming each phase voltage to a lower level using step down transformers. By the help of rectifiers these inputs voltages converted to DC, filtering methods done by capacitors then the inputs feds to Arduino Analog input pins for sensing purposes.

Table 4. 1: Materials used

No	Names	Quantity	Rating
1	Transformer	3	220/8 V
2	Arduino Uno	1	5V
3	GSM	1	5V
4	Diode	20	1N4007
5	Relay	3	5V
6	Resistors/ Variable	3	10K
7	Capacitors	9	100µF/3300 µF/104 Pf
8	Regulator	1	5V
9	LCD	1	5V
10	LED	3	5V

4.2: Results and Analysis

Experimental results show that if all phases are off also the load switched off but if one phase is available the load switched on (when supplied phase meet the standard voltage range).

When all phases are ON and meet the standard range the circuit allow the highest phase voltage to supply the load. If the allowed phase is overloaded the circuit automatically select another good power quality phase to supply load.

$$f(x) = \begin{cases} 1 \;\; if\; V_{R\,,Y,B}\; Min \leq V_{R,Y,B} Nominal \leq V_{R,Y,B} Max \\ 0 \qquad\qquad\qquad\qquad if\; V_{R\,,Y,B} < V_{R\,,Y,B}\; Min\; 0r \\ \qquad\qquad\qquad\qquad\quad V_{R\,,Y,B} > \;\; V_{R,Y,B} Max \end{cases} \qquad 4.1$$

Reference is made to the standard voltage range in Rwanda Where Vmin= 207 V and Vmax= 241.5 V

Table 4. 2: Truth Table

PHASE R	PHASE Y	PHASE B	LOAD
OFF	OFF	OFF	OFF
ON	OFF	OFF	ON-R
OFF	ON	OFF	ON-Y
OFF	OFF	ON	ON-B
OFF	ON	ON	ON-HIGH
ON	OFF	ON	ON-HIGH
ON	ON	OFF	ON-HIGH
ON	ON	ON	ON-HIGH

Figure 4. 1: Distribution pole

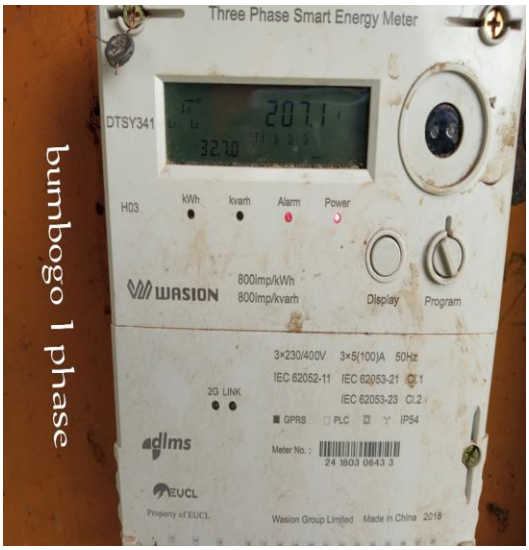


Figure 4. 2: 1st Phase Voltage

Figure 4. 3:2nd phase voltage

Figure 4. 4: 3rd Phase Voltage

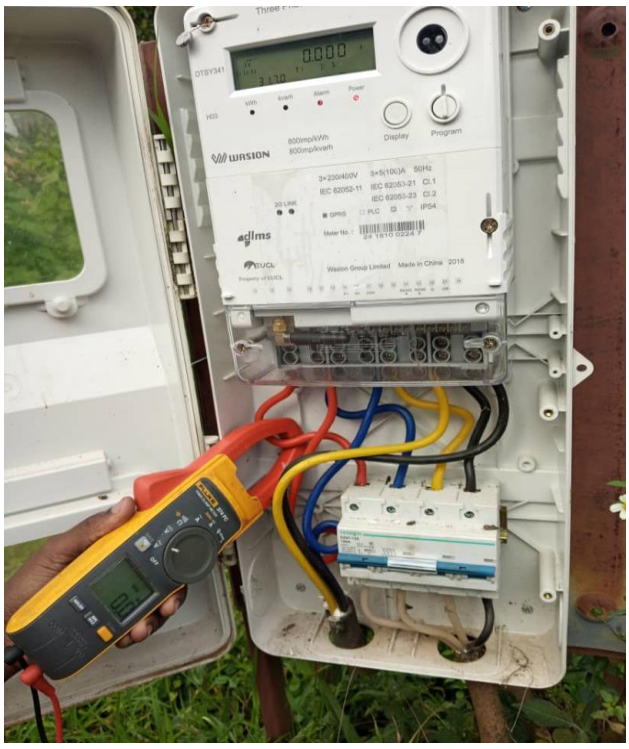


Figure 4. 5: OA For 1st Phase

Figure 4. 6: 9.9 A for second phase

Figure 4. 7: 10.2 A for 3rd phase

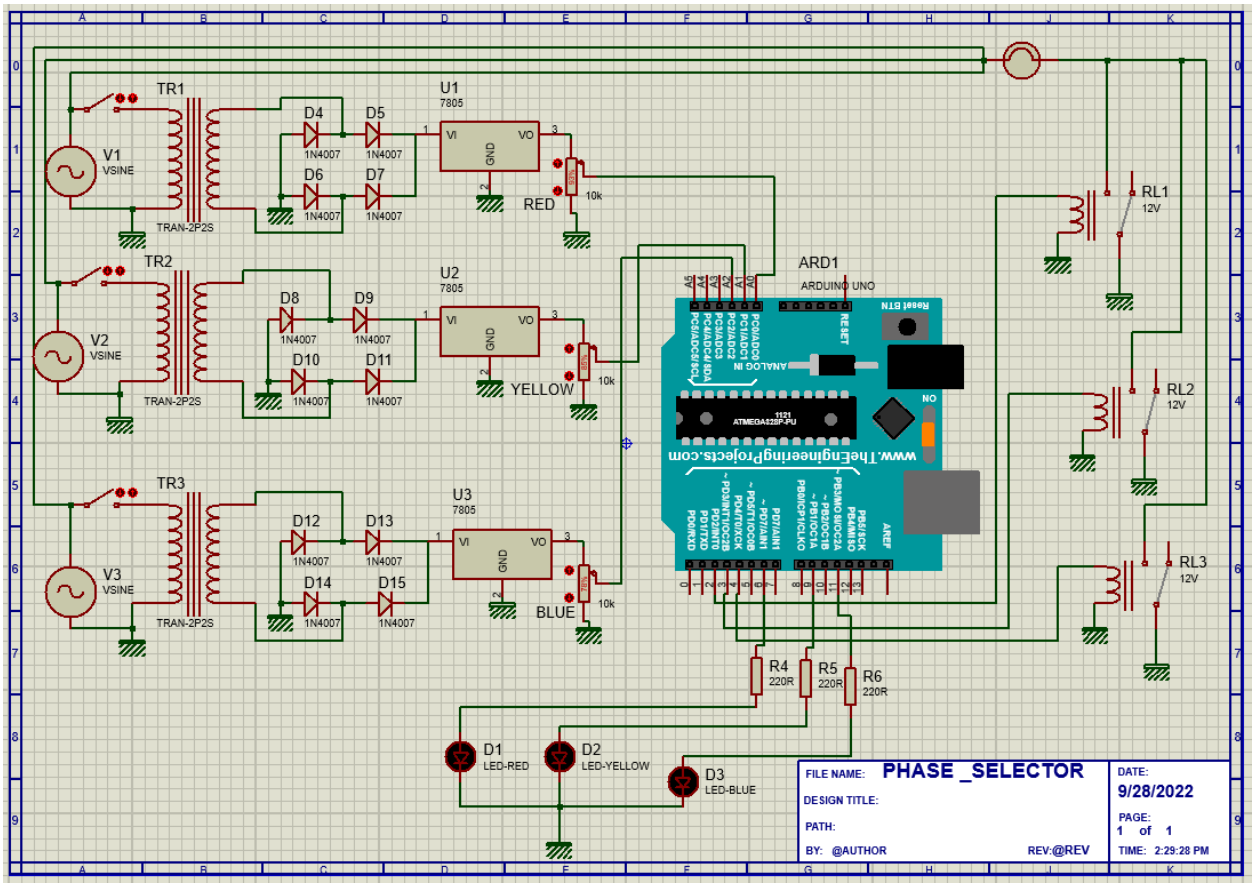


Figure 4. 8: Automatic Phase selector circuit

Working Principle of an Automatic Phase Selector

The circuit is made up with transformers, Arduino Uno, GSM, Diode, Relay, Variable Resistors, Capacitors, Regulator, LCD, and LED. Power supply from the grid is transformed to lower level using step down transformer from 220V to 8V. The low voltage is rectified using Bridge rectifier composed by 4, 1N4007 for each phase. As the output voltage from rectifier is not pure DC, filtering using capacitors helps to get pure DC to be fed to the analog input of Arduino. But as Arduino and GSM are more sensitive to the voltage increase that can leads to the damage, before fed voltage inputs to the Arduino supply there is a 5V Regulator in between. According to the program transferred to the Arduino using USB Cable, the Arduino compares the inputs then switch ON and OFF the relays according to the programmed instructions. According to the program the switching sequence is summarized in truth table.

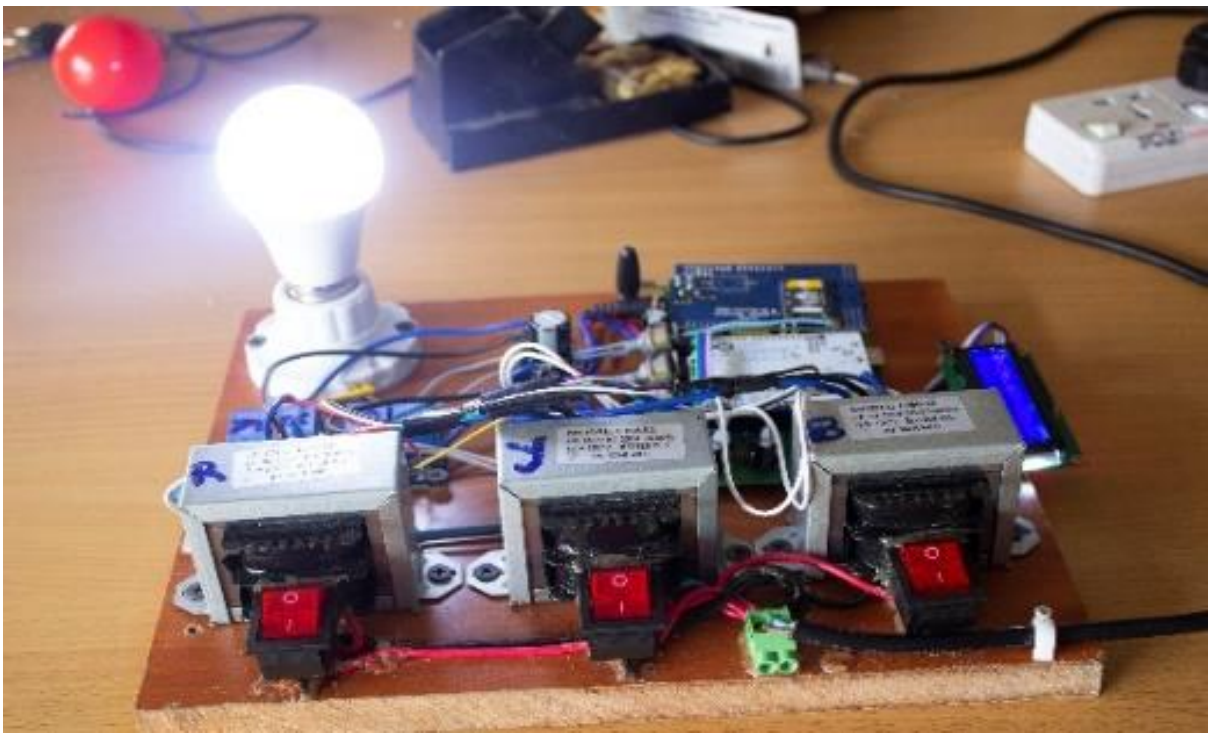


Figure 4. 9:Prototype

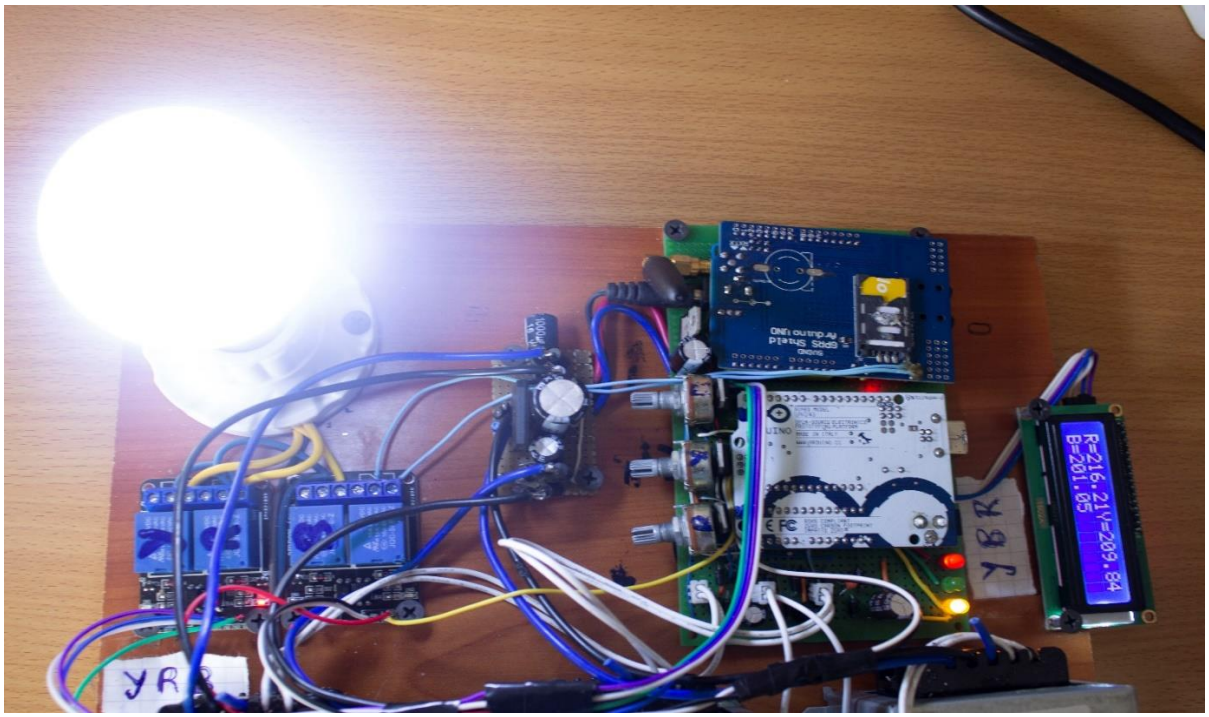


Figure 4. 10:Shows that only two phases (Red & Yellow) are within the voltage range

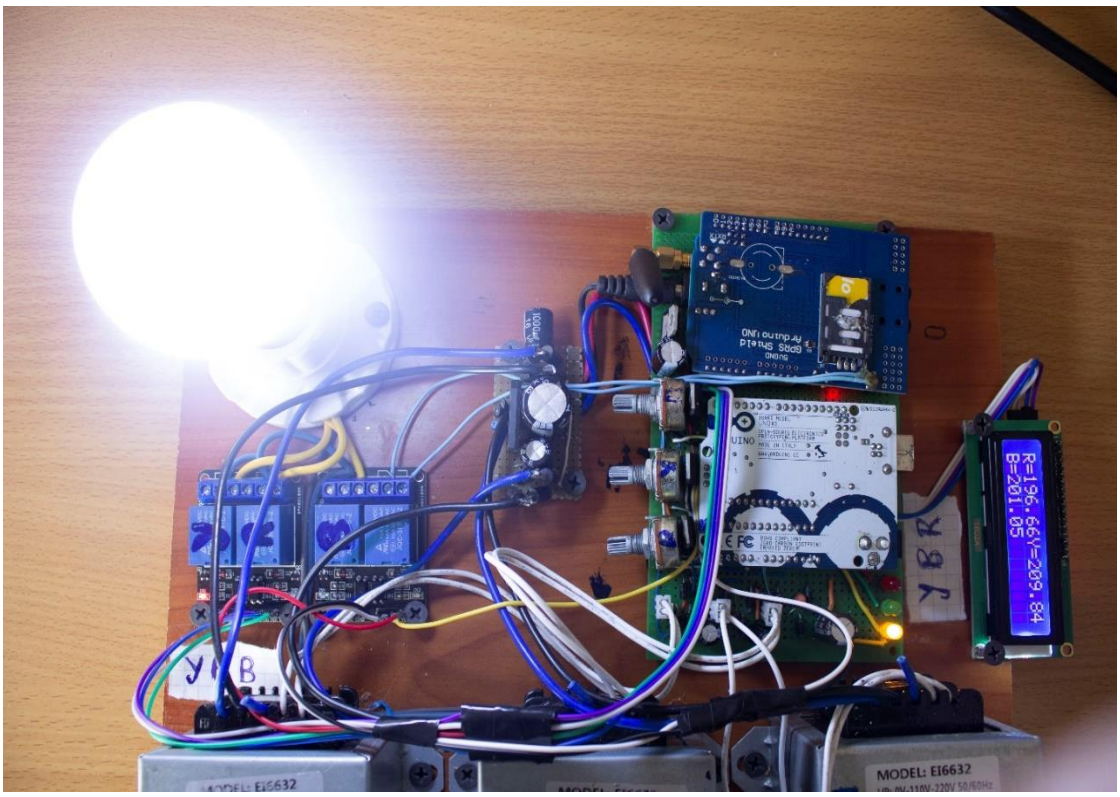


Figure 4. 11:: Shows that the load supplied by Yellow phase

Figure 4. 12:: Shows that if any phase is missing the utility Receive SMS.

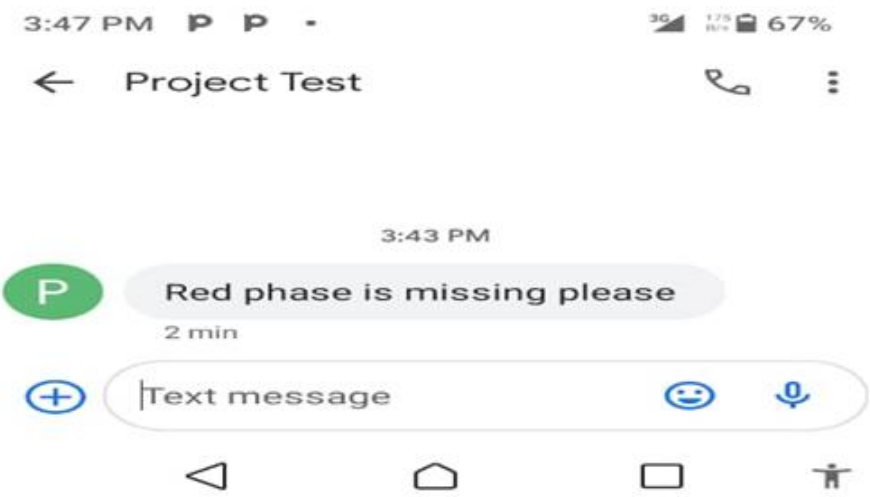


Figure 4. 13: Message shows that Red Phase is missing

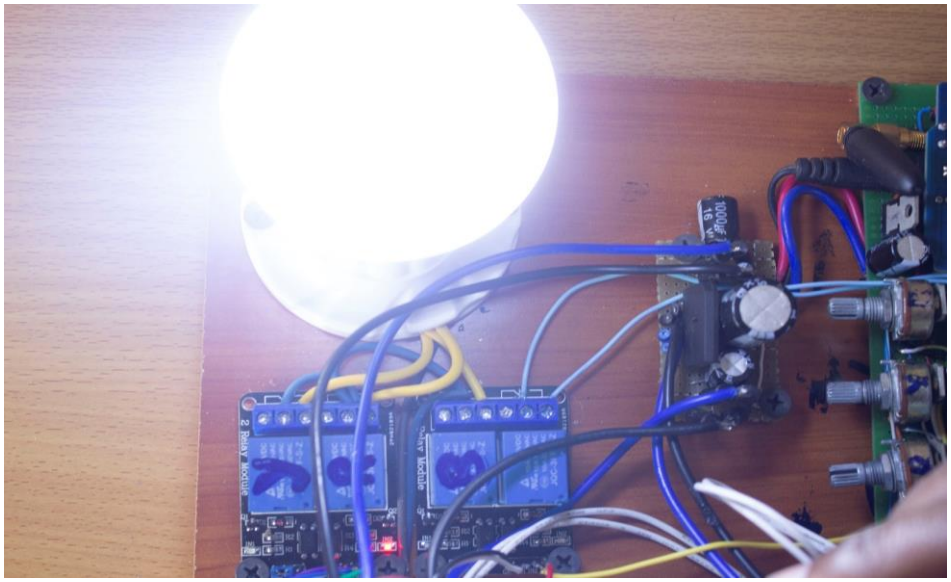
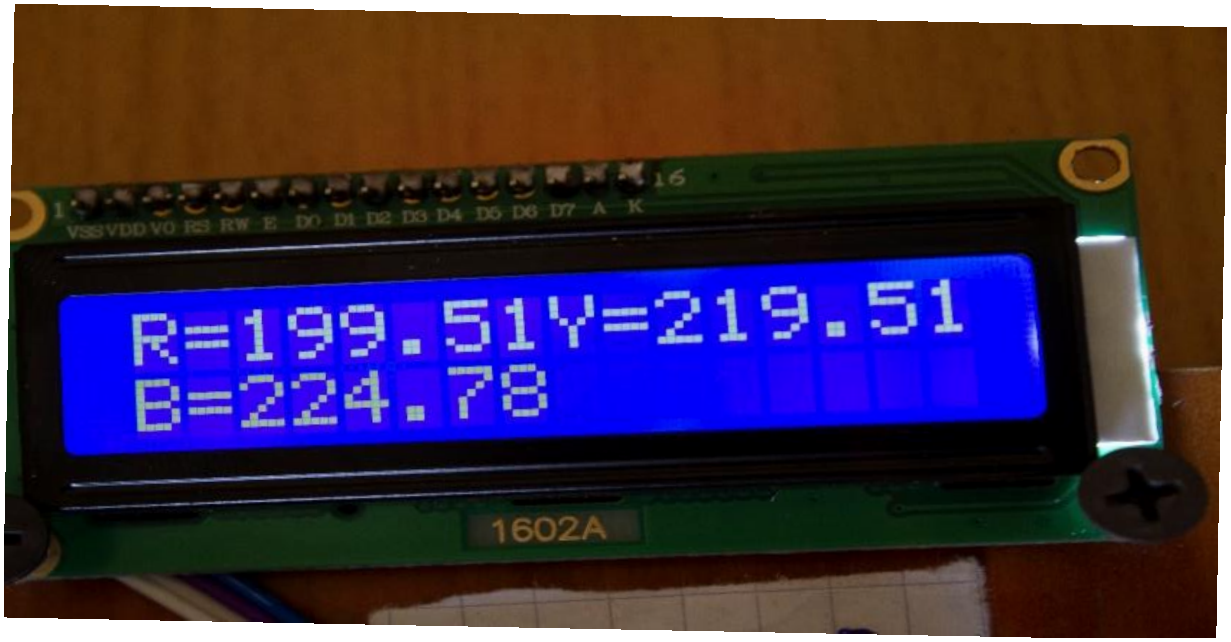


Figure 4. 14: Shows that Load supplied by Phase R



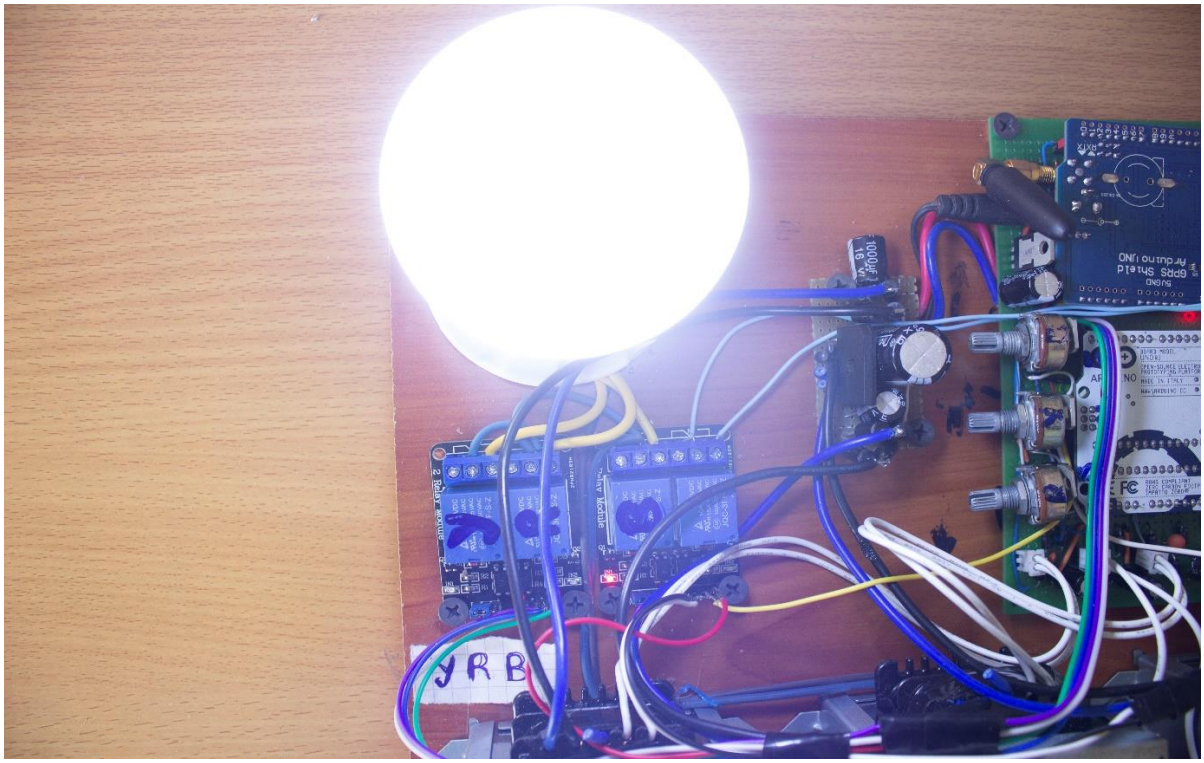


Figure 4. 15:: Shows that Load supplied by Phase B

Figure 4. 16:: Shows Voltage Imbalance due to Unbalanced Load

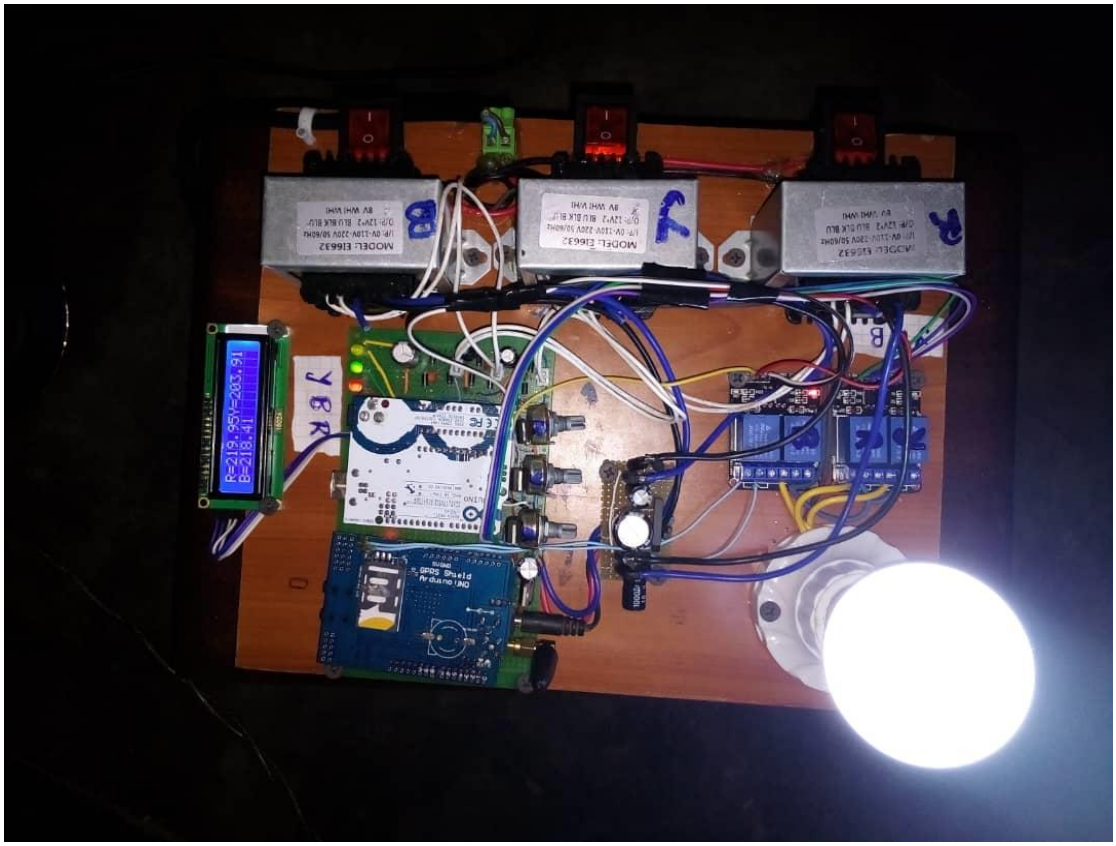


Figure 4. 17: Shows how load is still supplied by phase B even if phase R is higher than B

4.3: Validation of Results

Reference is made to an "Auto selection of any available phase in three phase supply system'' they didn't provide the way of sensing under-voltage in phases so that our load can be supplied by under voltage phase. However, for this circuit now we can sense the under-voltage so that loads cannot be supplied by substandard phase due to overloading.

Reference is made to the ''Design and construction of Automatic three phase power system selector'' they did not provide the way of informing the utility that there is a phase failure in a distribution line. Nevertheless, for this project the utility can be informed that there is a phase failure for quick intervention.

Reference is made to an '' Design analysis of an Automatic phase selector'' the delay between phase switching is 5 second but for this circuit there is no delay between phase selection when one phase failed.

Reference is made to the '' Design and simulation of Automatic phase selector and changeover switch for 3 phase supply'' The highest phase voltage is selected but this can reduce switching frequency when another phase becomes higher than the previous selected phase. However, this circuit provide the stability way of switching the phases.

Table 4. 3: Validation table

Ref	PREVIOUS WORK	EXPERMENTAL RESULTS
[13]	Didn't provide the way of sensing under-voltage	Voltage less than 207V can't supply load
[10]	Didn't provide the way of informing utility when phase missing	Utility informed when one or 2 phases are missing
[7]	Time delay for phase changing can even reach to 5 seconds	No time delay between phase selection
[20]	Reduce Switching frequency	Stability on switching phases

4.4: Conclusion

This chapter discuss the analog inputs to the circuit and lists all materials used for the experiment. This chapter also discuss the results obtained after implementation. The truth table is listed; for phase selection for example if Phase R is 196.66 V, phase Y is 209.84 V and phase B is 201.05 V the load supplied by Phase Y. But If another phase becomes higher than this value the circuit select that phase immediately. If the phase that supply the load becomes 0 Volt, the circuit automatically select another phase.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The supply in distribution system is of a three phase system but many loads are single phase. 3-phase distribution system face with voltage imbalance because of overloading one phase due to random connection of clients to the national grid. The load connected to an overloaded phase face with sub-standard voltage range. This can be solved by employing in a network, a device that can receive all phases and select the less loaded phase. Less loaded phase is characterized by high voltage compared to others and this selected phase is the one to supply the load. This reduce the power lost in distribution line even the load connected to under-voltage phase not operate well this project solve this issue as the under-voltage phase can't be allowed to supply the load. Referring to the experimental results we get the expected results from this automatic phase selector. When one phase is available our single phase load remains supplied. If the phase that previously supply our load is overloaded this circuit automatically select another phase that supply load without any notice to power failure. For example, if Phase R is 210V Phase Y is 2015V and Phase B is 220V, Phase B selected to supply the load as the highest Voltage.

Load can't be supplied by under-voltage phase (less than 207 Volts) and there is no delay between phase selection. If one phase is missing the utility informed for quick intervention. This project put end to the manual phase selection. This project sense input voltage for each phase and switch the load to a good phase. This project save time taken during manual phase selection. This project can be used in hospitals and it can save life in case of power failure when one phase is missing. This project reduce the effect caused by power instability thus improve the economic growth of the country. This project reduce the effect caused by manual selection including human electrocution. when all phases are within the accepted voltage range the highest phase voltage selected. If the selected phase is off due to fault or any other issue the device automatically selects another phase to provide the reliable power supply.

5.2 Contribution

Refer to the results obtained by previous researchers; this project provides the way of selecting good power quality phase without any delay for providing the reliable power supply. This automatic phase selector provides the quick way of informing the utility that there is a phase missing in the distribution network. this project also avoids the load to be supplied by under-voltage phase.

Normally when all phases are available and meet the range, the highest phase voltage is selected to supply the load. but this can reduce the switching frequency of relays due to the facts that voltage in AC change with time. Switching ON and OFF many times in short time on relay can cause the high voltage but in this project there is a stability way of switching the relays.

5.3: Recommendation

This device "Automatic phase selector" didn't provides the power to our load when all phases fails I recommend the future researcher to provide switching method that allows alternative power source to supply the load when main supply is completely off.

5.3.1: Further Work Improvement of This Project

In this project when one or two phases are missing the utility informed via SMS using GSM. For the improvement of this project; it is better to provide the way of using internet for providing the message informing the utility that there is a missing phase in distribution line somewhere.

5.3.2.: Adoption of Results

Distribution system is done in three-phase mode but many loads are single phase. Due to phase imbalance caused by overloading one phase when other phases are not overloaded, the load connected to an overloaded phase didn't function well. To solve this there is a need of using a device named Automatic Phase Selector, the inputs from the supply line are fed to this circuit then the selected phase supplies the load.

Institutions like hospitals, banks, residential houses and commercial buildings are recommended to use this technology. This technology helps the load to be continuously supplied even in case of power failure when one phase is missing and this technology save time taken to change the phase manually.

REFERENCES

[1] P. Awunde, E. Ashigwuike, and B. Emmanuel, "DESIGN, SIMULATION AND CONSTRUCTION OF AUTOMATIC THREE-PHASE POWER SELECTOR SYSTEM."

[2] S. U. Haq, B. Arif, A. Khan, and J. Ahmed, "Automatic three phase load balancing system by using fast switching relay in three phase distribution system," in *2018 1st International Conference on Power, Energy and Smart Grid (ICPESG)*, 2018, pp. 1-6.

[3] S. C. Ayan Ghosh, Snehashis Das, Kaustav Mallick, "Design of Automatic Phase Selector from Any Available Three Phase Supply," *International Journal of Scientific & Engineering Research,*, vol. 7, p. 4, 2016.

[4] E. K. Umaru, A. G. Aguto, E. Z. Kalyankolo, and E. Edozie, "Design and Implementation of an Android Based Automatic Phase Selector and Overload Protector Using GSM."

[5] D. Sarode, A. Wadhekar, and R. Autee, "Voltage source inverter with three phase preventer and selector for industrial application," in *2015 International Conference on Pervasive Computing (ICPC)*, 2015, pp. 1-4.

[6] C. I. Ahmed, "DESIGN AND IMPLEMENTATION OF A MICROCONTROLLER BASED AUTOMATIC THREE PHASE SELECTOR," *International Journal of Advance Research and Innovative Ideas in Education*, vol. 3, pp. 115-122, 2017.

[7] A. O. Owojori, A. M. Akinbolade, and K. Akingbade, "DESIGN ANALYSIS OF AN AUTOMATIC PHASE SELECTOR," *Journal of Engineering Studies and Research*, 2022.

[8] O. Lawal, A. Jimoh, and A. Lawal, "DESIGN AND IMPLEMENTATION OF A THREE PHASE 6KVA AUTOMATIC PHASE SELECTOR IN A THREE PHASE SUPPLY CIRCUIT," vol. 5, p. 1, 06/01 2017.

[9] P. Awunde and E. Ashigwuike, *DESIGN, SIMULATION AND CONSTRUCTION OF AUTOMATIC THREE-PHASE POWER SELECTOR SYSTEM*, 2021.

[10] F. U. Nweke and R. C. Iwu, "Design and Construction of Automatic Three Phase Power System Selector," 2015.

[11] M. S. D. S. Shubham V. Bansod1, Priti T. Indurkar,Prof. S. J. Tikhe, "To study an automatic power phase selector," vol. 3, p. 3, 2018.

[12] D. P. R. Ajith Kumar V, Fayis Muhammed T V ,Vishnu R, "Automatic Three Phase Selector with Power Factor Improvement," *International Research Journal of Engineering and Technology (IRJET)*, vol. 4, p. 3, 2017.

[13] P. Kumbhare, "Auto Selection of Any Available Phase in 3 Phase Supply System," *International Journal for Research in Applied Science and Engineering Technology*, vol. 6, pp. 2029-2033, 04/30 2018.

[14] L. Xiang-Ning, Z. Menghua, K. Alymann, and L. Pei, "Novel design of a fast phase selector using correlation analysis," *IEEE Transactions on Power Delivery*, vol. 20, pp. 1283-1290, 2005.

[15] P. Chang, G. Song, J. Hou, and R. Xu, "A novel voltage phase selector for inverter-interfaced system based on two-stage control strategy," *International Journal of Electrical Power & Energy Systems*, vol. 133, p. 107299, 2021/12/01/ 2021.

[16] L. L. Zhang, M. S. Li, T. Y. Ji, Q. H. Wu, L. Jiang, and J. P. Zhan, "Morphology Singular Entropy-Based Phase Selector Using Short Data Window for Transmission Lines," *IEEE Transactions on Power Delivery,* vol. 29, pp. 2162-2171, 2014.

[17] Z. Li, Z. Qingchun, L. Xiangning, and L. Pei, "Improved phase selector for unbalanced faults during power swings using morphological technique," *IEEE Transactions on Power Delivery,* vol. 21, pp. 1847-1855, 2006.

[18] Y. Yang, N. L. Tai, and W. Y. Yu, "ART artificial neural networks based adaptive phase selector," *Electric Power Systems Research,* vol. 76, pp. 115-120, 2005/09/01/ 2005.

[19] Z. Lu, W. H. Tang, T. Y. Ji, L. Jiang, and Q. H. Wu, "A phase selector based on mathematical morphology for double circuit transmission lines," in *2008 Third International Conference on Electric Utility Deregulation and Restructuring and Power Technologies*, 2008, pp. 2322-2327.

[20] G. Ofualagba and E. Udoha, "Design and Simulation of Automatic Phase Selector and Changeover Switch for 3-Phase Supply," *Int. J. of Nov. Res. in Elec. and Mech. Eng,* vol. 4, pp. 28-35, 2017.

[21] V. Bhat, "Design and Implementation of Auto-Phase Selector from Three-Phase Supply," *IUP Journal of Electrical and Electronics Engineering,* vol. 14, pp. 27-37, 2021.

[22] S. S. Vaidya, N. V. Hendwe, C. B. Bhagat, and P. Raut, "Automatic Cost Effective Phase Selector System," *International Journal of Research in Engineering, Science and Management,* vol. 3, 2020.

[23] M. Okundamiya and J. Erua, "The realization of a smart phase selector and changeover power switching system for a residential consumer," *World Journal of Biotechnology,* vol. 14, pp. 2038 – 2046, 08/01 2013.

[24] O. E.O and O. Joy.O, "A Microcontroller based Automatic 3-Phase Selector for Load Control in Home Applications," 2019.

[25] Y. A. Badamasi, "The working principle of an Arduino," in *2014 11th International Conference on Electronics, Computer and Computation (ICECCO)*, 2014, pp. 1-4.

[26] N. Tamkittikhun, T. Tantidham, and P. Intakot, "AC power meter design based on Arduino: Multichannel single-phase approach," in *2015 International Computer Science and Engineering Conference (ICSEC)*, 2015, pp. 1-5.

[27] M. E. a.-D. Ahmad, K. M. Matroud, H. N. Qasim, A. S. Fudeh, A. I. Naser, and T. Al Hassan, "Arduino Based Universal Motor Controller & Light DImmer," 2018.

[28] V. Sonandkar, A. Bhati, D. Gupta, S. Chouhan, N. Kinhekar, and N. P. Padhy, "Power measurement using arduino for effective demand response," in *2016 IEEE 6th International Conference on Power Systems (ICPS)*, 2016, pp. 1-5.

[29] S. Durrani, H. Arif, E. Ali, A. Ali, S. Khan, and H. Ali, "A smart framework for power distribution and load balancing using Arduino," in *2018 1st International Conference on Power, Energy and Smart Grid (ICPESG)*, 2018, pp. 1-6.

[30] H. S. E. Barkat and B. Mahdad, "An Experimental Educational Platform Based Arduino-GSM for Power System Protection," in *2018 International Conference on Communications and Electrical Engineering (ICCEE)*, 2018, pp. 1-6.

[31] K. S. Kaswan, S. P. Singh, and S. Sagar, "Role Of Arduino In Real World Applications," 2020.

APPENDIX 1

```
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2); // set the LCD address to 0x27 for a 16 chars and 2 line display OFFICIAL

int _timeout;

String number = "+250783709554"; //-> change with your number

//String number = "+250785501515"; //-> change with your number

//String number = "+250783857521"; //-> change with your number

int yellow = 11;

int blue = 9;

int red = 6;

int relayr = 3;

int relayy = 2;

int relayb = 5;

int gsm_reset = 8;


float phred = 0.00;

float phyl = 0.00;

float phybl = 0.00;

float VIn_a = 0.00;

float VIn_b = 0.00;

float VIn_c = 0.00;

float AC_Voltage_a = 0.00;

float AC_Voltage_b = 0.00;
```

```
float AC_Voltage_c = 0.00;
void setup() {
  Serial.begin(9600);
  digitalWrite(relayy, HIGH);
  digitalWrite(relayr, HIGH);
  digitalWrite(relayb, HIGH);
  pinMode(gsm_reset, OUTPUT);
  digitalWrite(gsm_reset, LOW);
  delay(2000);
  digitalWrite(gsm_reset, HIGH);

  pinMode(red, OUTPUT);
  pinMode(yellow, OUTPUT);
  pinMode(blue, OUTPUT);
  pinMode(relayr, OUTPUT);
  pinMode(relayy, OUTPUT);
  pinMode(relayb, OUTPUT);
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("initialazing");
  delay(2000);
```

```
 gsmInit();
}
void loop()
{
 readsensor ();
 swcondition();
 send_sms();
}
void readsensor ()
{
 phred = analogRead (A0);
 delay(10);
 phyl = analogRead (A1);
 delay(10);
 phybl = analogRead (A2);
 delay(10);
 VIn_a = ( phred * 5.00) / 1024.00;     //Convert 10bit input to an actual voltage
 AC_Voltage_a = (VIn_a * 45);
 VIn_b = ( phyl * 5.00) / 1024.00;     //Convert 10bit input to an actual voltage
 AC_Voltage_b = (VIn_b * 45);
 VIn_c = ( phybl * 5.00) / 1024.00;     //Convert 10bit input to an actual voltage
 AC_Voltage_c = (VIn_c * 45);
```

```
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("R=");
  lcd.setCursor(2, 0);
  lcd.print(AC_Voltage_a);
  lcd.setCursor(8, 0);
  lcd.print("Y=");
  lcd.setCursor(10, 0);
  lcd.print(AC_Voltage_b);
  lcd.setCursor(0, 1);
  lcd.print("B=");
  lcd.setCursor(2, 1);
  lcd.print(AC_Voltage_c);
  // all phase available
  if (AC_Voltage_a >= 207 && AC_Voltage_b >= 207 && AC_Voltage_c >= 207) {
    digitalWrite(red, HIGH);
    digitalWrite(yellow, HIGH);
    digitalWrite(blue, HIGH);
}
  //red only
  else if (AC_Voltage_a >= 207 && AC_Voltage_b < 207 && AC_Voltage_c < 207) {
    //LED
    digitalWrite(red, HIGH);
```

```
    digitalWrite(yellow, LOW);
    digitalWrite(blue, LOW);
}
  //yellow only
  else if ( AC_Voltage_c >= 207 && AC_Voltage_a < 207 && AC_Voltage_b < 207) {

    digitalWrite(yellow, HIGH);
    digitalWrite(blue, LOW);
    digitalWrite(red, LOW);
    }
  //blue only
  else if ( AC_Voltage_b >= 207 && AC_Voltage_a < 207 && AC_Voltage_c < 207) {
    digitalWrite(blue, HIGH);
    digitalWrite(red, LOW);
    digitalWrite(yellow, LOW);
}
  //red_blue
  else if (AC_Voltage_a >= 207 && AC_Voltage_b >= 207 && AC_Voltage_c < 207 ) {
    digitalWrite(red, HIGH);
    digitalWrite(blue, HIGH);
    digitalWrite(yellow, LOW);
}
  //red_yellow
```

```
  else if (AC_Voltage_a >= 207 && AC_Voltage_c >= 207 && AC_Voltage_b < 207 ) {
    digitalWrite(red, HIGH);
    digitalWrite(yellow, HIGH);
    digitalWrite(blue, LOW);
}
  // blue_yellow
  else if (AC_Voltage_a <= 207 && AC_Voltage_b >= 207 && AC_Voltage_c >= 207 ) {
    digitalWrite(blue, HIGH);
    digitalWrite(yellow, HIGH);
    digitalWrite(red, LOW);
}
   //all off
   else if (AC_Voltage_a == 0 && AC_Voltage_b == 0 && AC_Voltage_c == 0)
   {
    digitalWrite(blue, LOW);
    digitalWrite(yellow, LOW);
    digitalWrite(red, LOW);
    sendSMS("zone one blackout please?");
    delay(10000);
  }
   /*
//red missing
  if (AC_Voltage_a == 0 && AC_Voltage_b != 0 && AC_Voltage_c != 0) {
```

```
   sendSMS("Red phase is missing please?");
   delay(10000);
  }
  //blue missing
  else if (AC_Voltage_a !=0 && AC_Voltage_b == 0 && AC_Voltage_c!= 0) {
   sendSMS("blue phase is missing please?");
   delay(10000);
  }
  // yellow missing
   else if (AC_Voltage_a !=0 && AC_Voltage_b != 0 && AC_Voltage_c == 0) {
   sendSMS("yellow phase is missing please?");
   delay(10000);
   }
 //*/
else   {
   digitalWrite(blue, LOW);
   digitalWrite(yellow, LOW);
   digitalWrite(red, LOW);
}
  }

void swcondition() {
 float a=AC_Voltage_a+3;
```

```
  float b=AC_Voltage_b+3;
  float c=AC_Voltage_c+3;

  if (AC_Voltage_a >= 207||AC_Voltage_b >207||AC_Voltage_c >207){
if (AC_Voltage_a==AC_Voltage_b &&AC_Voltage_a==AC_Voltage_c)
    {
      digitalWrite(relayr, LOW);
      digitalWrite(relayy, HIGH);
      digitalWrite(relayb, HIGH);
    }
  if (a>AC_Voltage_b && a>AC_Voltage_c)
    {
      digitalWrite(relayr, LOW);
      digitalWrite(relayy, HIGH);
      digitalWrite(relayb, HIGH);
    }
   if (b>AC_Voltage_a && b>AC_Voltage_c)
    {
      digitalWrite(relayr, HIGH);
      digitalWrite(relayy, LOW);
      digitalWrite(relayb, HIGH);
    }
    if (c>AC_Voltage_a && c>AC_Voltage_b)
```

```
   {
     digitalWrite(relayr,HIGH);
     digitalWrite(relayy, HIGH);
     digitalWrite(relayb, LOW);
   }
  }

 else {
    digitalWrite(relayy, HIGH);
    digitalWrite(relayr, HIGH);
    digitalWrite(relayb, HIGH);
   }
 }
void send_sms(){

//red missing
  if (AC_Voltage_a == 0 && AC_Voltage_b != 0 && AC_Voltage_c != 0) {
    sendSMS("Red phase is missing please");
    delay(10000);
  }
  //blue missing
  else if (AC_Voltage_a !=0 && AC_Voltage_b == 0 && AC_Voltage_c!= 0) {
    sendSMS("yellow phase is missing please");
```

```
   delay(10000);
  }
  // yellow missing
   else if (AC_Voltage_a !=0 && AC_Voltage_b != 0 && AC_Voltage_c == 0) {
   sendSMS("blue phase is missing please");
   delay(10000);
   }
   //red_blue missing
else if (AC_Voltage_a ==0 && AC_Voltage_b== 0 && AC_Voltage_c != 0) {
   sendSMS("red and yellow phase is missing please");
   delay(10000);
   }
   // blue_yellow missing
  else if (AC_Voltage_a ==0 && AC_Voltage_b != 0 && AC_Voltage_c == 0) {
   sendSMS("red and blue phase is missing please");

   delay(10000);
   }
   // b&&y missing
  else if (AC_Voltage_a !=0 && AC_Voltage_b == 0 && AC_Voltage_c == 0) {
   sendSMS("blue and yellow phase is missing please");
   delay(10000);
   }
```

```
}



void sendSMS(String msg)
{
  Serial.println("AT+CMGF=1");
  delay(500);
  Serial.print("AT+CMGS=");
  Serial.print('"');
  Serial.print("+250783709554");    // enterphone_number
  //Serial.print("+250785501515");    // enterphone_number
  //Serial.print("+250783857521");
  Serial.print('"');
  Serial.println();
  delay(500);
  Serial.println(msg);
  delay(500);
  Serial.write(26);
  delay(1000);
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("SMS Sent");
```

```
  //Serial.print("SMS Sent");
  delay(2000);
  }
void gsmInit()
{
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("Finding Module..");
  boolean at_flag = 1;
  while (at_flag)
  {
    Serial.println("AT");
    while (Serial.available() > 0)
    {
      if (Serial.find("OK"))
        at_flag = 0;
    }
    delay(1000);
  }
  Serial.println("ATE0");
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("Finding Network..");
```

```
  boolean net_flag = 1;
  while (net_flag)
  {
    Serial.println("AT+CPIN?");
    while (Serial.available() > 0)
    {
      if (Serial.find("READY"))
        net_flag = 0;
      break;
    }
    delay(1000);
  }
  Serial.println("AT+CNMI=2,2,0,0,0");
  delay(1000);
  Serial.println("AT+CMGF=1");
  delay(1000);
  Serial.println("AT+CSMP=17,167,0,0");
  delay(1000);
  Serial.flush();
}
```

APPENDIX 2

3. DESIGN PHILOSOPHY

3.1 LOW VOLTAGE PHILOSOPHY

Where possible, the design can be scaled down for initial construction and upgraded later as follows:

- The design Voltage will be 400/230 Volt.
- Initial LV feeder is designed for the calculated long-term saturation load on the feeder
- LV Lines can stretch over two transformer zones initially, with only one transformer installed. The structure for the second transformer must be in place, and the second transformer is installed when the load or Voltage on the LV is outside acceptable limits.
- LV Networks and transformers must be designed and installed with easy upgrading in mind.
- The maximum permitted Voltage fluctuation at the end of the LV service connection (Customer supply point) shall not be more than +5% and -10% of nominal Voltage with the calculated saturation load.
- The network's design shall be overhead bundle conductor (ABC) radial systems. The covered neutral carrier system is in use. However, underground design can be recommended as required by the area to be connected and instructed by the Design Engineer.
- Line design shall be in two definite categories namely:
  - Main line construction normally of three phase construction with ABC conductors normally 70 mm^2 or 50 mm^2 conductor.
  - Spur line construction of three phase construction with conductors normally 35 mm^2 or 25 mm^2 ABC