# DESIGN AND CONSTRUCTION OF UNDERGROUND CABLE FAULT LOCATION AND NOTIFICATION SYSTEM

**BY**

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**16/A/BEE/0935/G/F**

**AN ENGINEERING PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, TECHNOLOGY, APPLIED DESIGN AND FINE ART, KABALE UNIVERSITY**

**IN PARTIAL FULFILLMENT OF THE REQIREMENTS FOR THE DEGREE OF BACHELOR OF ELECTRICAL ENGINEERING.**

**IN**

**ELECTRAL DEPARTMENT**

**JANUARY, 2021**

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**SUPERVISORS**

| SN | Name | Title | Signature & Date | Affiliation |
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# DECLARATION

I MUGISHA SIMON, declare that this report is the original copy of my written Project report.

Sign……………………………………

Name: MUGISHA SIMON

Date………………………………………

# APPROVAL

This is to certify that this project report is the original of the activities done during the Project.

Sign………………………………………………………………………

Supervisor's name……………………………………………………….

# DEDICATION

I give thanks to my parents Mr MUGISHA HILLARY and Mrs KYOGABIRWE CLOVENCE for their financial support to purchase the project components. I also appreciate the training officers and supervisors for guiding me through this Project.

# ACKNOWLEDEMENT

The success and final outcome of this final year project report required a lot of guidance and assistance from many people and I am extremely privileged to have got all this along the completion of my Project. I respect and thank the management and staff of Kabale University for organizing this useful project and the continuous inspection and supervision that was given to me through this project.

# ABSTRACT

The overhead lines are mostly used when compared to underground cables though in towns and cities, underground cables are preferred. The underground cables are largely used in urban areas instead of overhead lines. This is because they have minimized transmission losses, can lead to death of human beings and destruction of property like buildings. This comes as a result of tall buildings being near the conductors. In determining the location of a fault point in the underground cable, the AC power in the cables is first switched off because they cannot carry both AC power and DC power at once and the standard concept of Ohms law is applied that is, when a low DC voltage is applied at the feeder end through a series resistors representing the cable lines, then current would vary depending upon the location of the fault point in the cable. In case there is a short circuit (Line to Ground), the voltage across series resistors changes depending on the fault location. This voltage is then fed to an Analogue to Digital Converter (ADC) to develop precise digital signal and the Arduino nano communicates the LCD screen to display the status of the underground cables by showing the fault location (distance) in kilometers with its respective phase.

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

**LED** - Light Emitting Diode

**GSM -** Global Service for Mobile communication

**SIM -** Subscriber Interface Module

**ADC** - Analogue to Digital Converter

**km** - kilometer

**CRO** - Cathode Ray Oscilloscope

**LG-**Line to Ground

**LLG-**Double line to Ground

**LLLG-**All lines to Ground

**PB-**Push button

# TABLE OF CONTENTS

# CHAPTER ONE: INTRODUCTION

## 1.1 Background to the problem

Generally, overhead lines are mostly used when compared to underground cables, though towns and cities, the underground cables are preferred. The underground cables are widely used in urban areas instead of overhead lines. This is because they have minimized transmission losses and due to tall buildings which cause obstructions to the overhead lines, and can cause death of human beings [1]. When the underground cables are used and the faults occur in them, it becomes difficult to identify the faults.

## 1.2 Existing system

The more technologies and models are currently developed to evaluate the underground cables but there is little relation between the diagnosed results (the results obtained after fault) and actual results (the results obtained before occurrence of a fault). The underground power distribution failure represents a threat to power infrastructure. Since the cable replacement is expensive, the replacement must be selectively.

On consultation with UMEME Kabale Branch, it is found that fault detection of underground cable is among the complicated activities they carry out in the field. The existing system only detects the faults and locates them. These existing systems do not have notification system which sends a message to the phone after detection and location of a fault. Therefore including a GSM module for calling and sending the message to a phone after detection and location of a fault point would be a good idea.

## 1.3 Proposed system.

The proposed system detects the fault, locates the fault and sends the message to the phone. This message sent to the phone contains the fault and the location of the fault. This system locates short circuit faults in the underground cable. The cables have some resistance therefore this resistance varies with respect to the length of the cable meaning that the resistance of the cable is directly proportional to its length. Hence if the length of the underground cable increases, its resistance value also increases. Any deviation that occurs in the resistance value causes a fault in underground cable. The point at which the fault occurs is known as the fault point and this point represents the standard of distance in kilometers from the base station.

## 1.4 Problem statement

The proposed system is meant to address the problem of finding the location of the fault point, sending a message and calling after location of a fault in long underground cable, and it becomes difficult to keep the records for detection and location of a fault. The messages sent to the phone after locating the fault point are stored in the phone hence keeping the records.

Therefore, this system calls and sends a message to the phone after detecting and allocating the fault point and this helps in determination of the distance of the fault from the base station.

## 1.5 Objectives

### 1.5.1 General objectives

To design and construct underground cable fault location and notification system.

### 1.5.2 Specific objectives

1. To determine the location of the fault point.
2. To design a layout of the proposed system.
3. To construct the system with a notifier.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Background

A bundle of electrical conductors used for carrying electricity is known as a cable. An underground cable typically has one or additional conductors coated with appropriate insulation and a protective covering. A fault in an underground cable can be any defect that diverts the trail of current and this affects the performance of the cable .So it's necessary to correct the fault that occurs in every underground cable. The power distribution can be done both in overhead line underground cables. However, the overhead cables are subjected to effects of snow, thunder, lightning and other environmental factors such as temperature. This requires cables with increased safety, high dependability, strength and greatest service. Therefore the underground cables are most popular in several areas particularly in urban places because of tall buildings. Since it is simple to discover and rectify the faults in overhead lines by mere observation, it is therefore impracticable in an underground cable. As they are buried deep within the soil, it is hard to discover the abnormalities in them. Even once a fault is found, it is very hard to discover the precise location of the fault. This ends up in digging up the whole area to discover and rectify the fault. This in turn causes the wastage of labour and money. Therefore it is necessary to grasp the precise location of faults within the underground cables. Regardless of the fault is, the voltage of the cable has the tendency to vary a fault has been found [2].

## 2.2 Comparison of benefits and downsides of the underground cables over those of the Overhead lines

### 2.2.1 Benefits of Overhead lines

- ❖ It is simple to repair and maintain the overhead lines.
- ❖ They are not restricted by landscape that's why they can be simply put in over stream or unsmooth regions like hills.
- ❖ Chances of electrocution are less because they have a big clearance from the ground.
- ❖ Cheaper to setup compared to underground transmission.

### 2.2.2 Downsides of Overhead lines

- ❖ These lines visually cover big areas wherever they are installed.

- These lines are affected by corona discharge and also subjected to lightning.
- Sometimes these lines are approached by the birds and low flying aircrafts or drones which might be dangerous to them.

## 2.3 Techniques for locating faults in underground cables

### 2.3.1 Cable Thumping For Locating Underground Cable Faults

A cable thumper is essentially a transportable high voltage surge generator. It is accustomed inject a high voltage DC surge (about 25 kV) into the faulty cable. If you provide a sufficiently high voltage to the faulty cable, the open-circuit fault can break down making a high-current arc. This high current arc makes a characteristic thumping sound at the precise location of the fault.

To find the location of cable fault exploitation the thumping technique, a thumper is about to thump repeatedly then walking on the cable route to listen to the thumping sound. This technique is helpful for comparatively shorter cables. For extended cables, the thumping technique becomes impossible (imagine walking on a cable that runs many kilometers to listen to the thump).

**Advantages and downsides of Cable Thumping**

A major advantage of cable thumping is that it will find electrical circuit faults accurately. Also, this technique is simple is straightforward to use similarly as easy to find out. The thumping technique provides terribly correct fault location, it's its own drawbacks. Applying this technique for extended cables is very long. It should take hours or maybe days to steer on the cable to find the fault. Moreover, throughout that point, the cable is exposed to high voltage surges. Therefore whereas the prevailing fault is found, the high voltage surges might weaken the insulation of the cable. If you are practiced in cable thumping, you will limit the injury to the cable insulation by reducing the ability sent through the cable to the minimum needed to conduct the check. Whereas moderate thumping might not cause noticeable injury, frequent thumping might degrade the cable insulation to an unacceptable condition. Also, this system cannot notice faults that do not arc-over that is tangency faults.

### 2.3.2 A Time Domain meter (TDR)

This sends a short-duration low energy signal (of regarding 50 V) at a high repetition rate into the cable. This signal reflects back from the point of modification in Ohmic resistance within the cable (such as a fault). The TDR shown in figure 1 works on the similar principle as that of a radio detection and ranging. A TDR measures the time taken by the signal to mirror back from the point of modification in Ohmic resistance. The reflections can be traced on a graphical display with amplitude on Y-axis and therefore the time on X-axis. The period of time varies with the fault location. If the injected signal encounters associate circuit (high impedance), it leads to high amplitude upward deflection on the trace. Whereas just in case of a short-circuit fault, the trace can show a high amplitude negative deflection [3].

Figure 1: Time domain meter

**Advantages and drawbacks of TDR**

As a TDR sends an occasional energy signal into the cable, it causes no degradation of the cable insulation. This can be a significant advantage of mistreatment TDR to seek out the point of a fault in associate underground cable. A TDR works well for open-circuit faults yet as conductor to conductor shorts. A weakness of TDR is that it cannot locate the precise location of faults. It offers approximate distance to the point of fault. Once the TDR sends a check pulse, reflections that will occur throughout the time of outgoing check pulse could also be obscured from the user. A TDR cannot see high resistance (generally higher than two hundred Ohms) ground fault. If there's encompassing electrical noise, it's going to interfere with the TDR signal. As the low-tension TDR is unable to spot high resistance ground faults, its effectiveness

## 2.4 Description on components used.

**A relay module**

A relay is electrically and automatically operated switch. Several relays use electromagnet, however alternative operative principles are used, like solid-state relays. Relays are used wherever it's necessary to control a circuit by a separate low-power signal. The primary relays were utilized in long distance telegraph circuits as amplifiers. The relays were used extensively in phone exchanges and early computers to perform logical operations. A sort of relay which will handle the high power needed to directly management an electrical motor or alternative hundreds is termed a contractor. Solid-state relays management power circuits with no moving elements, instead employing a conductor to perform switch. The relays with graduated operative characteristics and typically multiple operative coils are safe guard electrical circuits from overload or faults.

## DC-DC Buck Converter


Figure 1**:** The dc-dc buck converter

**Basic switching converter**

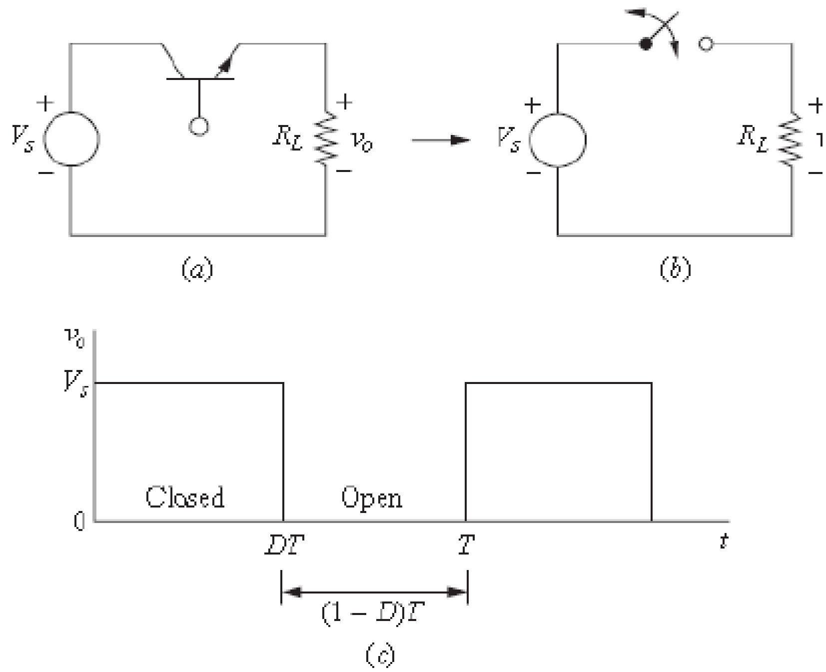


Figure 2: Basic switching convertor

When the switch is assumed to be ideal in the figure 3 above, the output is the same as the input when the switch is closed, and the output is zero when the switch is open. The periodic opening and closing of the switch leads to the pulse output of figure 3c. The average DC component of the output voltage is given by,

$$V_o = \frac{1}{T}\int_0^T v_o(t)dt = \frac{1}{T}\int_0^{DT} V_s(t)dt = V_s D \quad \text{……………………………(i)}$$

$V_O$= Average output voltage, T= Periodic time, D= Duty cycle and $v_o$= Input voltage

The DC component of the output voltage can controlled. This is achieved by adjusting the duty ratio D, which is the fraction of the switching period that the switch is closed. D is given by,

$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{T} = t_{on} f \quad \text{……………………………….... (ii)}$$

Where f is the switching frequency.

The DC component of the output voltage is less than or equal to the input voltage. The power absorbed by the perfect switch is zero. Once the switch is open, there is no current in it; once the switch is closed, there is no voltage across it. Therefore, all power is absorbed by the load, and therefore the energy efficiency is 100%. The losses can occur in a very real switch as a result of the voltage across it. A way of getting a DC output from the circuit of figure 3 is to insert a low-pass filter when the switch. Figure (4) below shows an LC low-pass filter other to the basic converter.

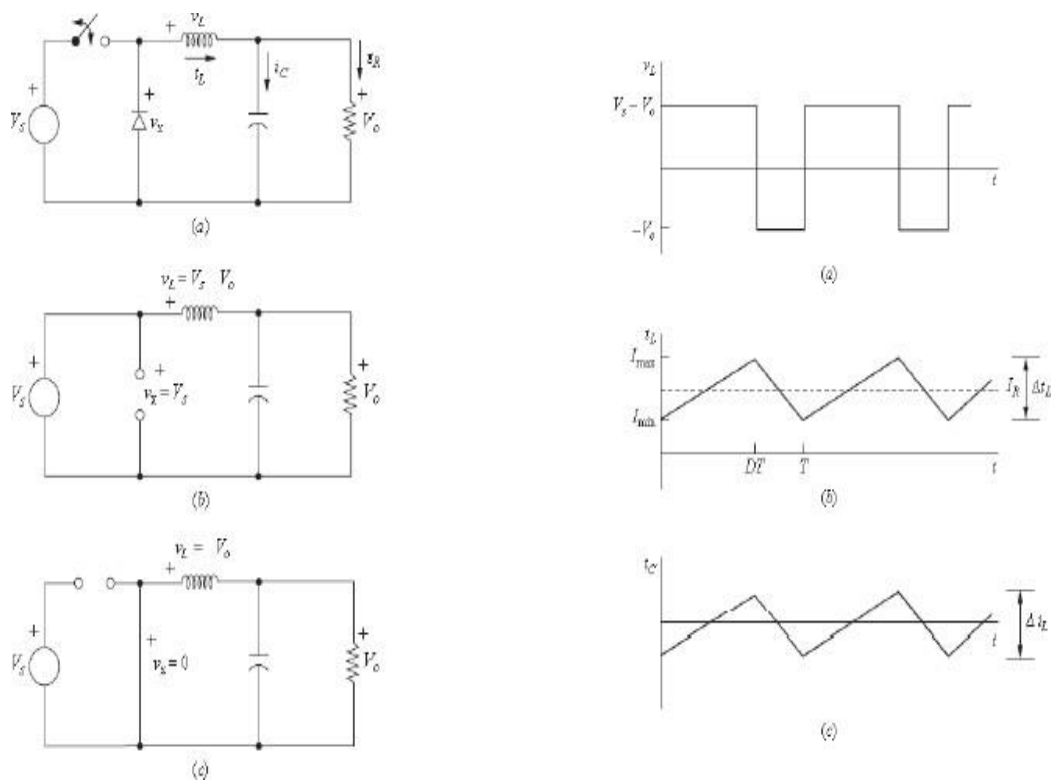


Figure 3: LC low pass filter added to the basic converter

If the low-pass filter is assumed to be ideal, the output voltage is the average of the input voltage to the filter. The input to the filter is Vs in figure 3 a. When the switch is closed and is zero once the switch is open, providing the inductance current remains positive, keeping the diode on. If the switch is closed sporadically at a duty ratio D, the voltage at the filter input is VsD, as in equation (i).This analysis assumes that the diode remains forward-biased for the complete time once the switch is open, implying that the inductance current remains positive. Buck converters and DC-DC converters generally, have the subsequent properties when operating within the steady state:

The inductor current is periodic and it is given by,

$$i_L(t+T) = i_L(t) \quad \text{.................................. (iii)}$$

The average inductor voltage is zero and is given by,

$$V_L = \frac{1}{T}\int_t^{t+T} v_L(\lambda)d\lambda \quad \text{.................................... (iv)}$$

The average capacitor current is zero and it is given by,

$$I_C = \frac{1}{T}\int_t^{t+T} i_C(\lambda)d\lambda \quad \text{....................................... (v)}$$

The power supplied by the source is equal as the power delivered to the load. For non-ideal components, the losses are also supplied by the source.

$$P_s = P_o \qquad \text{ideal}$$
$$P_s = P_o + losses \qquad non\ ideal \quad \text{.............................. (vi)}$$

By analyzing the buck converter of figure 4a, the following assumptions are made:

- The circuit works within the steady state.
- The electrical device current is continuous (always positive).
- The capacitor is extremely big, and therefore the output voltage is kept constant at voltage capacitance.
- The switching period is T; the switch is closed for time DT and open for time (1 − D) T

- The parts are ideal.

The key to the analysis for determination of the output Vo is to look at the inductor voltage and inductor current for the switch closed and so for the switch open. The net change in inductor current should be zero for steady state operation. The average inductor voltage is zero.

**Buck converter analysis**

**Switch closed:**

When the switch is closed, the buck converter circuit of figure 3a, the diode is reverse-biased and figure 3b is the same circuit. The voltage across the inductor and it is given by,

$$v_L = V_s - V_o = L\frac{di_L}{dt} \quad \text{.........................................} \text{(vii)}$$

$$\frac{di_L}{dt} = \frac{V_s - V_o}{L}, \qquad \text{switch closed} \quad \text{............................} \text{(viii)}$$

Since the derivative of the current is a positive constant, the current increases linearly as shown in figure 3b of buck converter waveform. The change in current when the switch is closed is computed by modifying the preceding equation as follows

$$\frac{di_L}{dt} = \frac{\Delta i_L}{DT} = \frac{V_s - V_o}{L}$$

$$(\Delta i_L)_{closed} = \left(\frac{V_s - V_o}{L}\right) DT \quad \text{..........................................} \quad \text{(ix)}$$

**Switch open;**

When the switch is open, the diode becomes forward-biased to carry the inductor current and the equivalent circuit of figure 3c applies. The voltage across the inductor when the switch is open is given by,

$$v_L = -V_o = L\frac{di_L}{dt} \quad \text{.......................... (xii)}$$

$$\frac{di_L}{dt} = \frac{V_o}{L}, \qquad \text{switch open} \quad \text{.............. (xiii)}$$

The derivative of current in the inductor is a negative constant, and the current decreases linearly. When the switch is opened, the change in inductor current is given by,

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = -\frac{V_o}{L}$$

$$(\Delta i_L)_{open} = -\left(\frac{V_o}{L}\right)(1-D)T \quad \text{.......................... (xiv)}$$

To attain the steady-state operation the inductor current at the end of the switching cycle should be equal to that at the beginning, which means that the net change in inductor current over one period is zero. This is given by,

$$(\Delta i_L)_{closed} + (\Delta i_L)_{open} = 0 \quad \text{................. (xv)}$$

$$\left(\frac{V_s - V_o}{L}\right)(DT) - \left(\frac{V_o}{L}\right)(1-D)T = 0 \quad \text{.................. (xvi)}$$

$$V_o = V_s D \quad \text{............................................... (xvii)}$$

The DC-DC buck converter produces the output voltage which is less than or equal to the input.

**Transformer**

Transformers convert AC electricity from one voltage to a different with very little loss of power. Transformers work solely with AC and this can be one amongst the explanations why mains electricity is AC. Change of magnitude transformers increase voltage, reduction transformers cut back voltage. Most power supplies use a step-down transformer to cut back the hazardously high mains voltage to a safer low voltage. Transformers waste little or no power therefore the power out is almost equal to input. Note that as voltage is stepped down while current is stepped up. The input coil is named the first and also the output coil is named the secondary. There is no electrical connection between the 2 coils, instead they are coupled by alternating flux created within the soft-iron core of the electrical device. The 2 lines within the middle of the circuit image represent the core as shown within the figure 6. The low voltage AC output is appropriate for lamps, heaters and special AC motors. It is not appropriate for electronic circuits unless they embody a rectifier and a smoothing capacitance. With solely an electrical device, the wave kind is as shown within the figure 4.

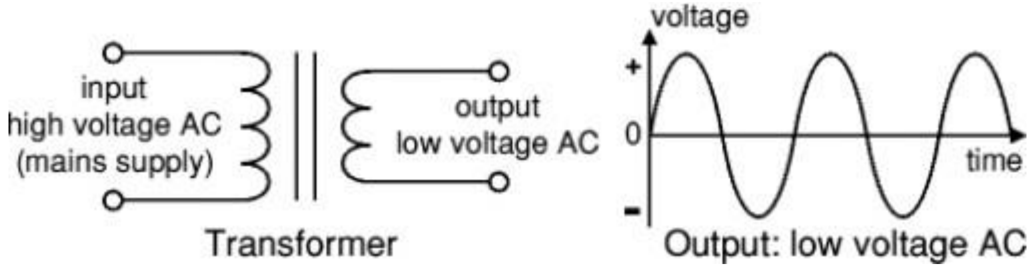


Figure 4: Transformer and output; low voltage AC

**Arduino nano**.

**Arduino nano** is a small, flexible, compatible and breadboard friendly microcontroller board, developed by Arduino.cc in Italy, based on ATmega328p [4].

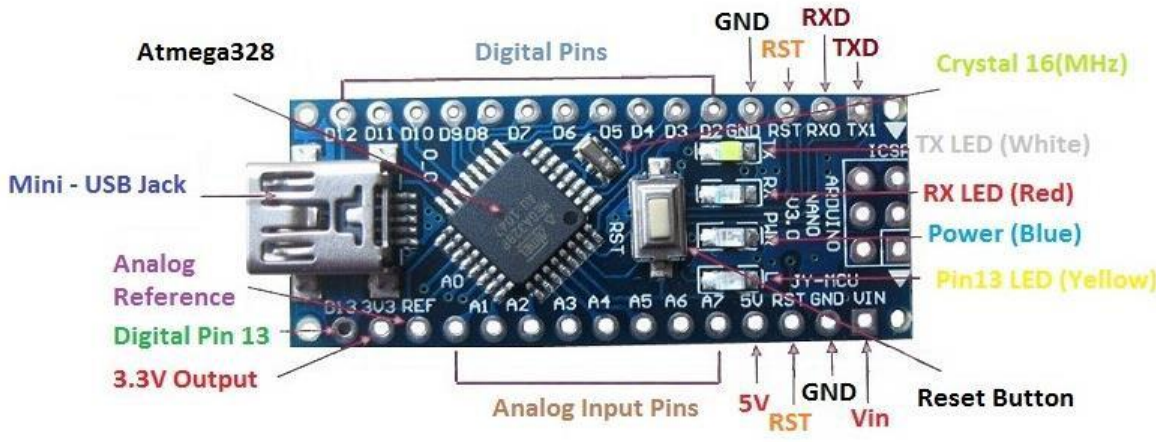


Figure 5: Pin outs for Arduino nano

**Arduino Nano Features**

- Tmega328P microcontroller is from 8-bit AVR family
- Analog I/P pins are six (6) from A0 to A5
- Digital pins are fourteen (14)
- Power consumption is nineteen (19) mA
- EEPROM is one (1) KB
- CLK speed is sixteen (16) MHz
- Weight = 7 g
- Size of the printed circuit board is 18 mm X 45 mm
- Operating voltage is 5 V
- Input voltage (Vin) is 7V to 12 V
- Input/output Pins ar twenty two
- Supports 3 communications like SPI, IIC, & USART
- I/O pins DC Current is forty mA
- Flash memory is thirty two K

• SRAM is two K

**Arduino Nano Pin out**

Arduino nano pin configuration is shown below and the function of each pin is discussed below.

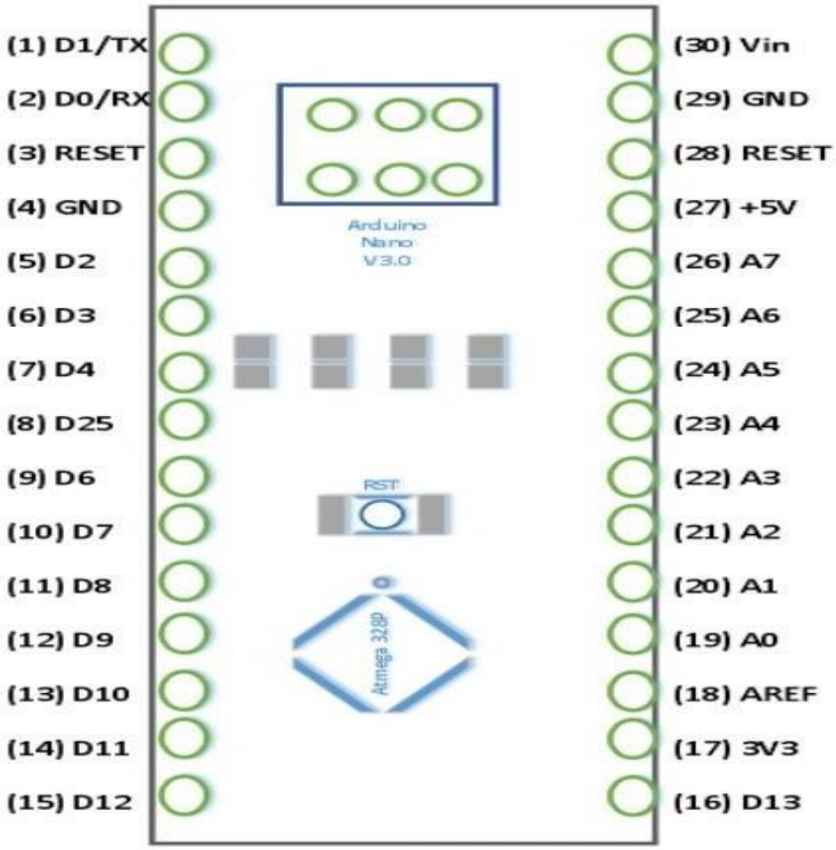


Figure 6: Arduino nano pin out

$V_{in}$ is the Arduino nano input voltage, and it is used when an external power source is required from 7 V to 12V.


Figure 7: The VIN provision

5 V is the Arduino nano board regulated power supply voltage and it is used to give the supply to the board and even components that do not consume much power like LCD screen.

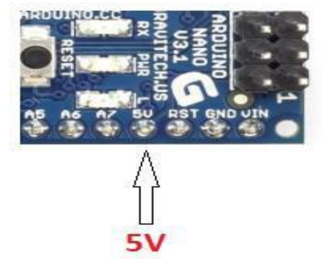


Figure 8: The 5V provision

3.3 V is the minimum voltage which is produced by the voltage regulator on the Arduino nano board.

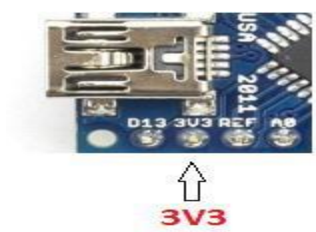


Figure 9: The 3.3 V provision

**GND**. This is the ground pin of the board

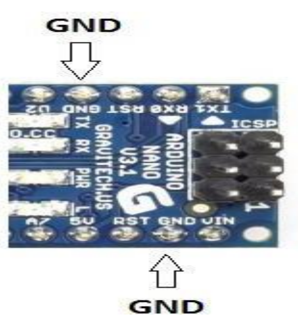


Figure 10: The Ground provision

**RST Pin (Reset):** This pin is used to reset the Arduino nano board.

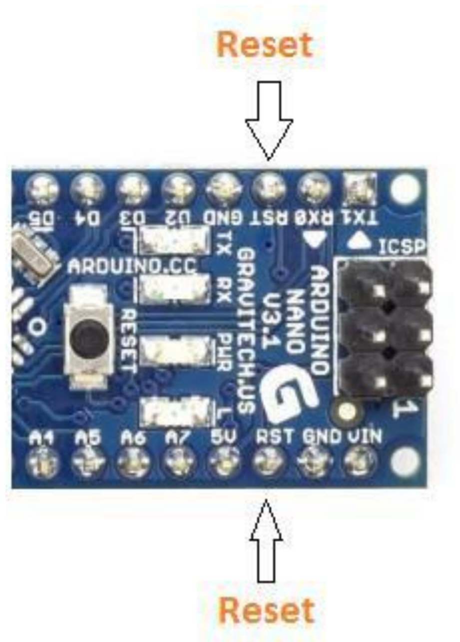


Figure 11: The Reset pin provision

**Analog Pins (A0-A7):** They are used to determine the analog voltage of the board within the range of 0 V to 5 V

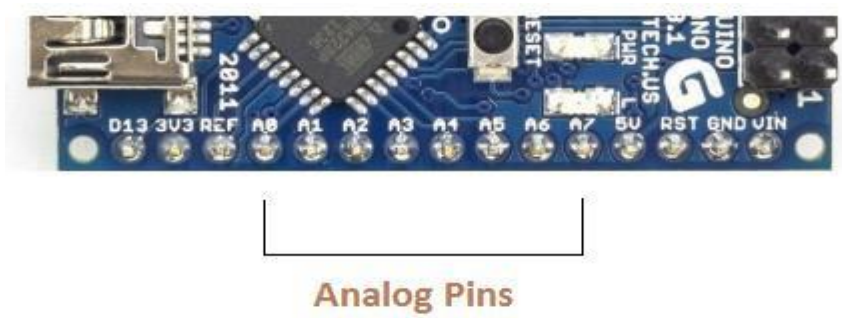


Figure 12: The Analog pins

**I/O Pins (Digital Pins from D0 – D13):** They are used as an i/p otherwise o/p pins. 0V & 5V

**Serial Pins (Tx, Rx):** They are used to transmit & receive TTL serial data.

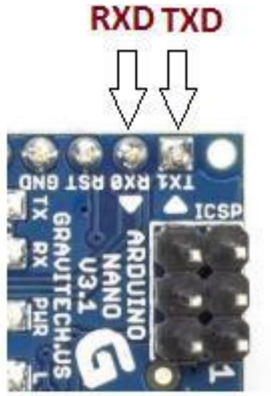


Figure 13: The Tx and Rx

**External Interrupts (2, 3):** They are used to activate an interrupt.

**PWM (3, 5, 6, 9, and 11):** They are used to provide 8-bit of PWM output.

**SPI (10, 11, 12, & 13):** They are used for supporting SPI communication.

**Inbuilt LED (13):** It is used to activate the LED.

**IIC (A4, A5):** They are used for supporting TWI communication.

**AREF:** It is used to give reference voltage to the input voltage

**Difference between Arduino UNO and Arduino Nano**

The Arduino Nano board is the same as An Arduino UNO board together with same microcontroller like Atmega328p. Therefore they share a same program. The distinction between these 2 microcontroller is that the size. The Arduino Uno size is double to Nano board. Thus Uno boards use extra space on the system. The programming of UNO may be through with a USB cable whereas Nano uses the mini USB cable.

**Diodes**

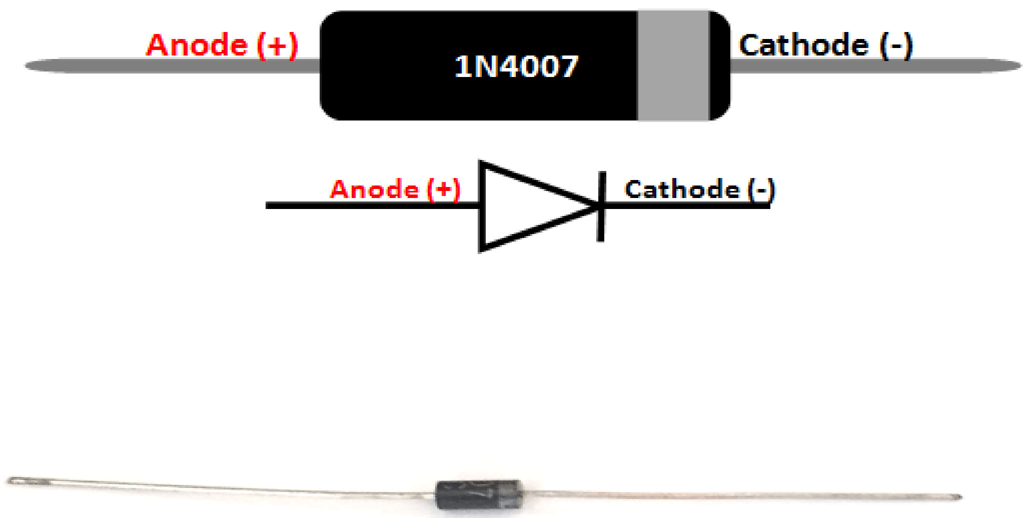


Figure 14: The 1N4007diodes

**Pin Configuration**

**Table 1: Pin configuration**

| Pin No. | Pin Name | Description |
|---|---|---|
| 1 | Anode | Current always Enters through Anode |
| 2 | Cathode | Current always Exits through Cathode |

**Features:**

- The average forward current is 1A
- The Non-repetitive Peak current is 30A
- The Reverse current is 5uA.
- The Peak repetitive Reverse voltage is 1000V
- The Power dissipation 3W

**Capacitors**

A capacitor may be a device that stores power in an electrical field. It's a passive electronic part with 2 terminals. The impact of a capacitor is thought as capacitance. Whereas some capacitance exists between any 2 electrical conductors in proximity in an exceedingly circuit, a capacitor may be a part designed to feature capacitance to a circuit.

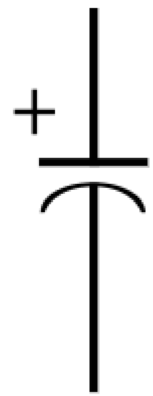


Figure 15: The polarized condenser image

**Vero boards**

Vero board is a complete of strip board, a pre-formed printed circuit material of copper strips on an insulating guaranteed paper board that was originated and developed within the early Nineteen Sixties by the physical science Department of Vero preciseness Engineering Ltd. It had been introduced as an all-purpose material to be used in constructing electronic circuits differing from purpose-designed computer circuit boards in this a range of electronic circuits could also be created employing a customary wiring board**.**

Figure 16: The Vero boards

**LEDs**

A LED is a semiconductor diode that emits light once current flows through it. Electrons within the semiconductor recombine with electron holes, emotional energy is produced inform of photons.

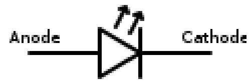


Figure 17: The semiconductor diode image

**LM7805 regulator**

The LM7805 transformer could be a constant  linear regulator   integrated circuit (IC). It belongs to the 78xx family. This xx is output voltage. The 7805 has an output Voltage of 5  V.

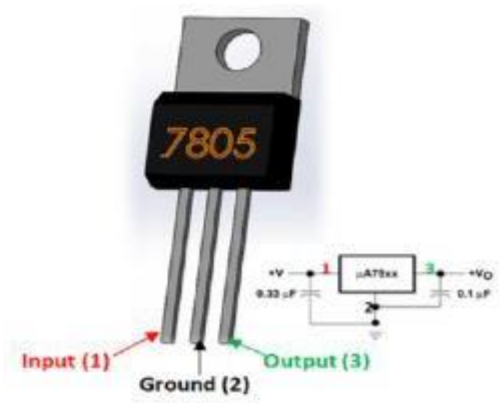


Figure 18: The LM7805 transformer

**The GSM (SIM800L)**

This is a miniature cellular module that permits for GPRS transmission, receiving and sending short sent messages (SMS), and creating and receiving voice calls. It is a small module when compared with SIM 800A and it has a quad band which make it suitable for long range connectivity. When connecting, the module boots up and searches for cellular network, and login automatically. On the board, there is an LED that indicates the status of connectivity and when it is not connected to the network, the LED blinks very fast but when it is connected to the network, the LED blinks very slow.

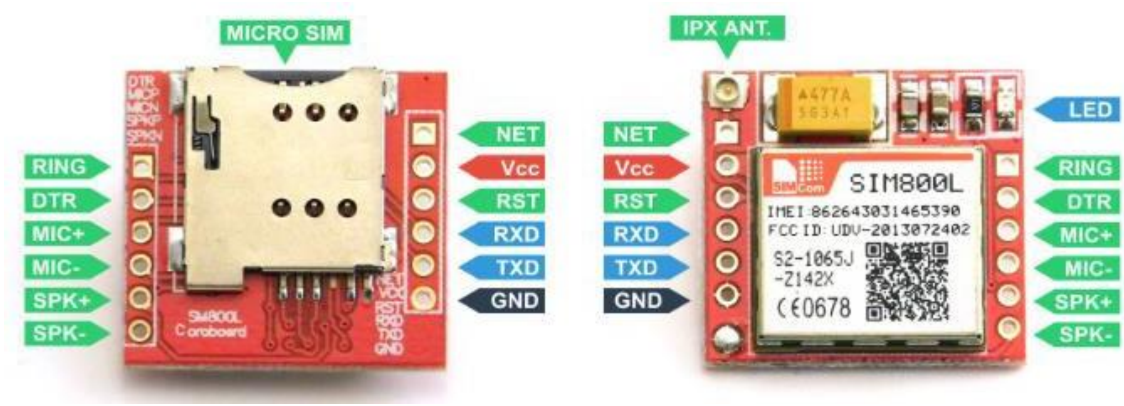


Figure 19: The pin out of the SIM800L

**Pin out (from bottom side to left):**

**RING**. This is for LOW state while receiving call

**DTR**. It is for sleep mode. When the module in sleep mode, serial communication is disabled

**MICP, MICN**. These are for microphone.

**SPKP, SPKN**. They are for speaker.

**Pin out (from bottom side to right):**

- **NET**. This is the provision for antenna
- **VCC**. This is for power supply
- **RESET**. This is for reset.
- **RXD**. It is for serial communication
- **TXD**. It is also for serial communication
- **GND**. It is for ground

**Power supply**

The low voltage AC output is appropriate for lamps, heaters and special AC motors. It's not appropriate for electronic circuits unless the rectifier and transformer are used. With solely transformer, the wave type of the low AC voltage created is shown in figure 20. With electrical device (transformer) and rectifier, the variable DC voltage is created and it's not suitable for powering electrical circuits therefore smoothing capacitor is required. The output from the electrical device is fed to the rectifier. It converts A.C. into pulsing D.C. In this project, a bridge rectifier is employed because it has a high efficiency .The circuit has four diodes connected to make a bridge [5].

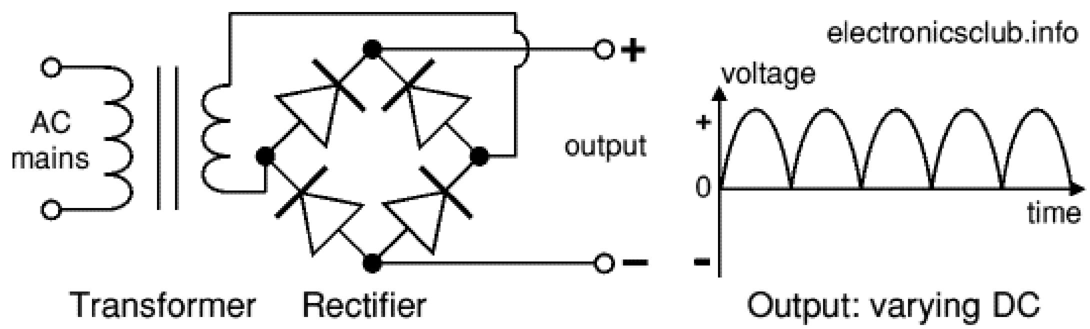


Figure 20: The variable DC output wave shape

When the smoothing is carried out within the circuit, a varying DC voltage is achieved and it's appropriate for powering electronic circuits. The smooth DC output contains little ripples. The wave form of the smooth DC voltage is shown in figure 21.

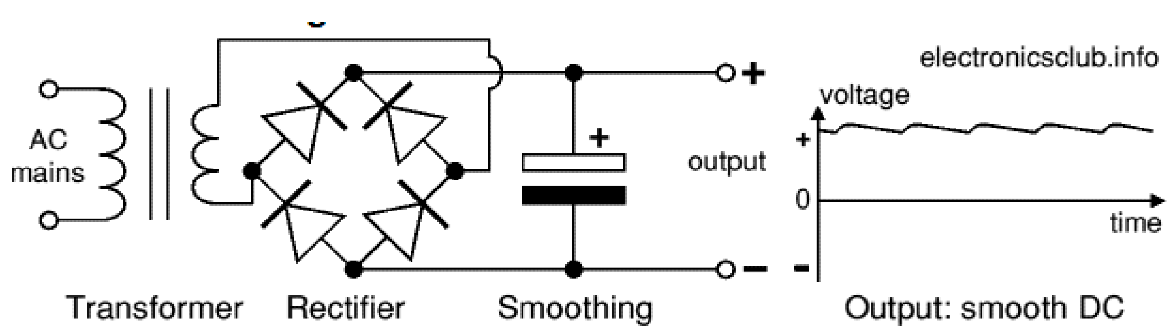


Figure 21: The DC output wave shape

## 2.5 Techniques of fault location

**Online technique**

The online technique uses and processes the sampled current and voltages to work out the fault points.

**Offline technique**

This technique uses a special instrument to check out the service of cable within the field. The offline technique is classified into 2 ways like the tracer technique and therefore the terminal technique.

**Tracer technique**

In this technique fault of the cable may be detected by walking on the cable lines. The fault location is denoted from the magnetic attraction signal or loud signal.

**Terminal technique**

The terminal technique is employed to find the location of the fault during a cable from one end point. This technique is employed to search out general areas of the fault to accelerate trailing on buried cable [6].

## 2.6 short circuit faults

A short circuit fault happens once there is an insulation failure between conductors or between conductor(s) and earth. An insulation failure results into formation of a contact path that enables currents to flow within the circuits [7]. Short circuit fault may be divided into 2 categories, specifically symmetrical and unsymmetrical faults. In symmetrical fault, 3 phases are short circuited. In unsymmetrical fault, the magnitude of this isn't equal and displaced by one hundred twenty degrees.

### 2.6.1 Types of short circuit faults

**Line to ground (LG)**

This happens when a single conductor comes into contact with the ground. This is the most common fault that happens in the power systems. The short circuit currents flow only in line L1 to the ground as shown in figure 22.

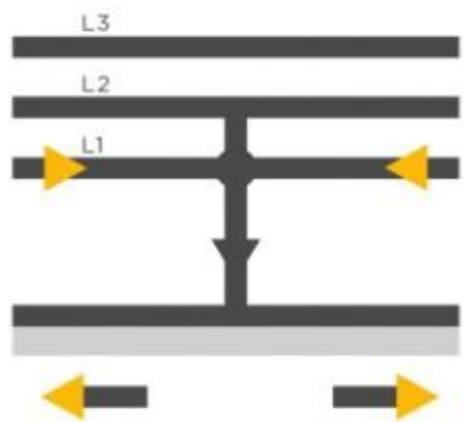


Figure 22: Line to earth fault

**Line-line to ground (LLG)**

This happens when two conductors come into contact with the ground and the short circuit currents only flow in conductors L1 and L3 to ground as shown in figure 23.

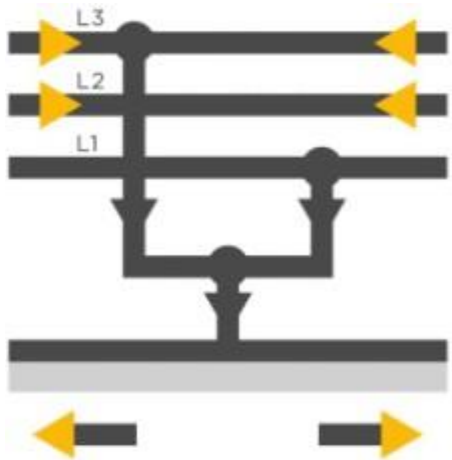


Figure 23: Line-line to ground fault

**Line-line-line to ground (LLLG)**

This happens when all the three conductors come into contact with the ground. This fault does not usually occurs but it is more dangerous if it happens in a power system. The short circuit currents flow in all conductors as shown in figure 24 [8].

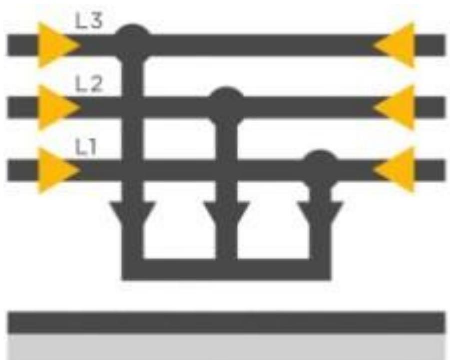


Figure 24: Line-Line-Line to ground fault

CHAPTER THREE: METHODOLOGY

## 3.1 Location of the fault point.

During determination of a fault point within the underground cable, the Ohms law is employed where DC voltage is applied at the feeder point end through a series of resistors representing Cable lines, then current would vary according to the location of the fault within the cable. When a short circuit (Line to Ground), the voltage across series resistors changes consequently, that is then fed to analogue to digital converter (ADC) to develop precise digital information that the Arduino nano would interpret and communicate with the LCD screen to show the location of the fault point in kilometers (km). The each phase is represented with a group of four 1 k resistors and this represents the length of a cable in kilometer, and fault creation is created by a series of four push buttons connected along each cable. When the fault occurs in a particular cable, then a signal is sent to the microcontroller to interpret the analogue signal to digital signal. After interpretation, it communicates with the LCD screen to display the output [9].

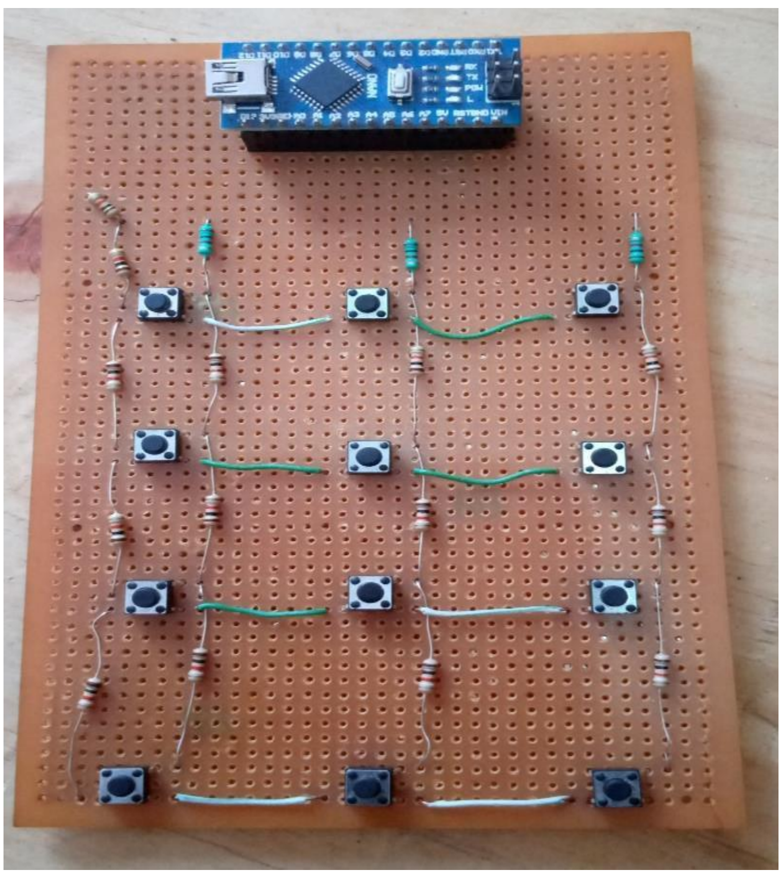

Figure 25: Building the fault setup

## 3.2 Layout of the proposed system.

### 3.2.1 The diagram

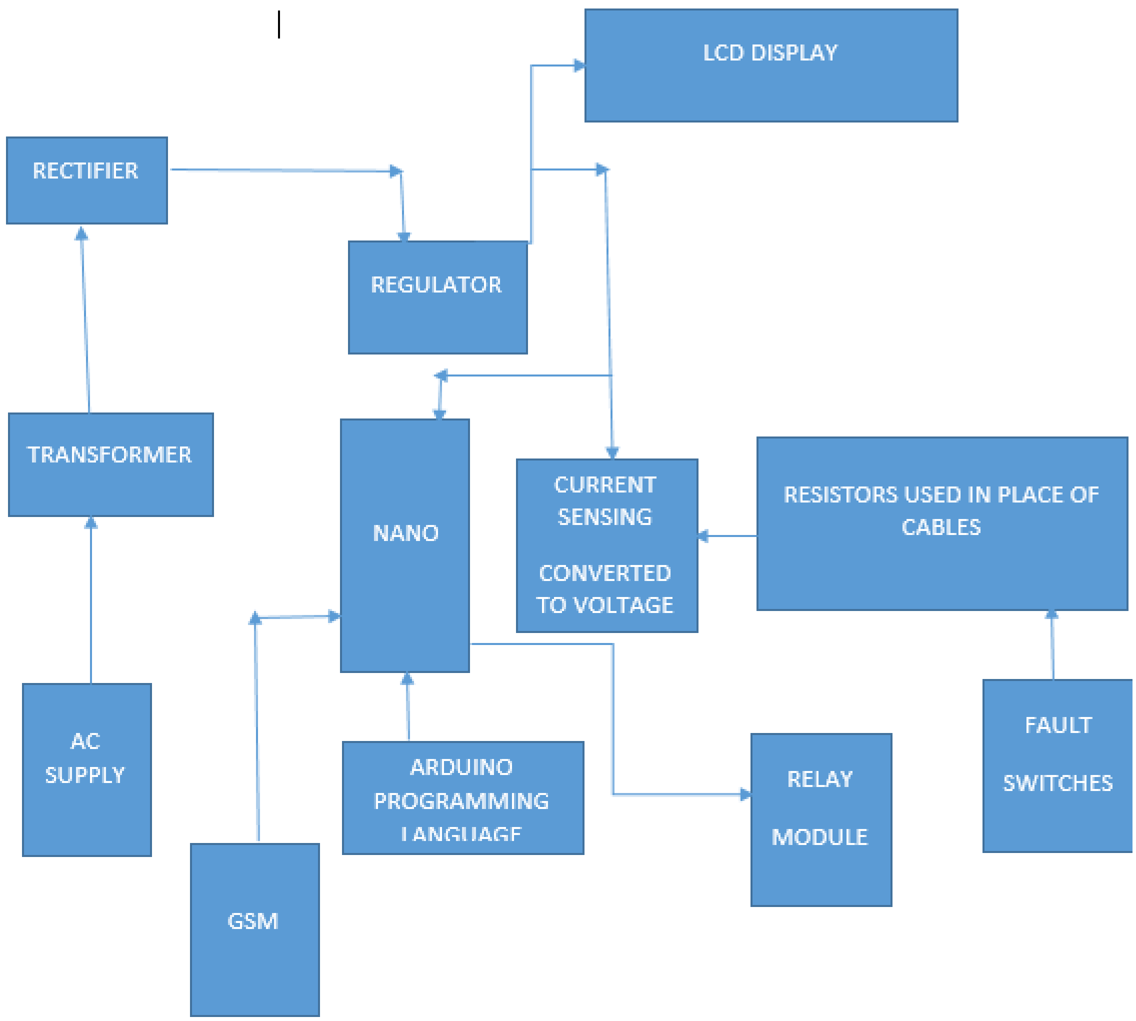


Figure 26: The block diagram of the system

This project is assembled with a group of resistors that represents the cable's length in kilometers and fault creation consists of a group of switches on each two kilometers. The fault creation is feasible by pressing on a push button. Figure 26 is that the model for the planned underground cable fault location and notification system mistreatment the Arduino nano. It is divided into 5 sections include; the DC power supply, cable section, controlling section, notification and display section. The DC power supply consists of AC supply, transformer, rectifier and voltage regulator. The alternating voltage of 230 V is stepped-down by the transformer, bridge rectifier converts the

AC voltage to DC voltage whereas the regulator is to produce a steady constant voltage. The cable is presented by a group of resistors with push buttons. The present sensing half on the cable painted as a group of resistors and switches used as fault creator to specify a fault at every location. Controlling section comprises of ADC which is the relay module that converts input signal from the current sensing circuit. The ADC converts input analogue voltage signal to digital voltage signal which is then sent to the microcontroller. The display section has an LCD screen which outputs the status of the cables and the location of the fault point. The notification section has a GSM module that either sends a message to the phone or calls when location of a fault point has been simulated.

### 3.2.2 The circuit diagram of the 9 V and 5 V power offer of underground cable fault location and notification system.

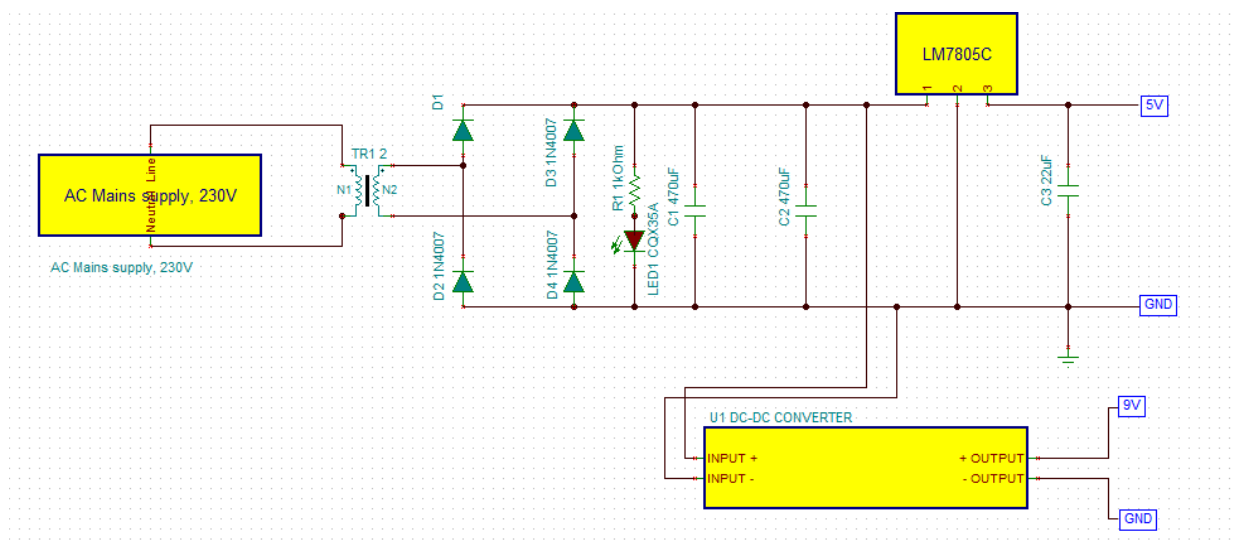


Figure 27: The 5 V and 9 V power supply circuit

The circuit shown in figure 27 consists of a 230 V step down transformer that steps down a voltage from 230 V to 8 V. A bridge rectifier uses four 1N4007 diodes and this is where rectification is done. An LED indicates that the circuit is ON and 1 k resistor that limits the current from burning the LED, capacitors for smoothing and filtering out the ripples, voltage regulator that outputs a 5

V constant regulated voltage. An LM2956 DC-DC HW-411 Buck device that converts 9.7 V to 9.0 V that's used for powering Arduino nano is used.

### 3.2.4 Design calculations of a 5 V power supply for underground cable fault location and notification system.

**Selection of regulator IC**

The selection depends on the output voltage needed. For instance in case 5 V is required. Thus the LM7805 linear regulator IC is chosen. The voltage, current and power ratings of the chosen regulator IC have to be accounted for. This can be done by using the datasheet of the regulator IC.

The following are ratings for LM7805 got from the datasheet.

Input voltage varies from 7 V to 35 V

Output voltage; Vmax = 5.2 V and Vmin = 4.8 V

Current rating is 1 A

The datasheet of 7805 additionally prescribes to use a 0.1 μF electrical capacitor at the output side of the voltage regulator to avoid transient changes within the voltages because of changes within the load however this value of electrical capacitor isn't simply found thus capacitance value of 470 μF is employed and a 0.1 μF at the input side of the regulator to avoid ripples if the filtering is much a way from the regulator, however it's not simply got thus a 22 μF electrical capacitor is employed.

**Selection of electrical device (transformer)**

A step down transformer that steps down from 230 V to 8 V because the minimum input voltage to the regulator is 7 V, as stated in the datasheet.

But between the regulator and secondary side of the electrical device, there's a diode bridge rectifier that contains a drop of 1.4 V. So, its secondary voltage can be calculated as below.

$$V_{secondary} = 7\ V + 1.4\ V = 8.4\ V\ (\text{peak value})$$

Therefore this means that a transformer with secondary voltage of 8 V is chosen.

From the above points, for 5 V DC power supply design, a transformer of current rating 1 A is selected. This is because the regulator IC has a current rating of 1 A, so a current more than 1 A cannot be used.

**Selection of diodes for bridge**

When selecting a diode for the bridge circuit, the output load current and maximum peak secondary voltage should be considered. The selected diode must have the current rating more than the load current that is 500 mA.

**Selection of smoothing capacitor and calculations**

When selecting a recommended capacitor filter, voltage, power rating and capacitance value have to be considered. The voltage rating is obtained from the secondary voltage of a transformer.

Hence the capacitance value is given by,

$$C = \frac{I_0}{2\pi f V_0}$$

where $I_0$ = load current = 500 mA, $V_0$ = output voltage = 5 V, f = 50 Hz.

$$C = \frac{500}{2\pi * 50 * 5} = 3.1847 * 10^{-4}\ \text{F}$$

The capacitance value close to practical standard capacitance value is 470 µF.

### 3.2.5 Design calculations for fault setup

For all phases

The resistance, R of a cable is directly proportional to the length, l of the cable and it is given by,

$$R \propto l$$

$$R = k_1 l \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (i)$$

where $k_1$ is a constant.

The resistance, R of the cable is inversely proportional to the cross sectional area, A of the cable and it is given by,

$$R \propto \frac{1}{A}$$

$$R = k_2 \frac{1}{A} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (ii)$$

where $k_2$ is a constant.

Combining equations (i) and (ii)

$$R = k \frac{l}{A}$$

where $k$ is a constant.

But $k = \rho$

where $\rho$ is resistivity

$$R = \rho \frac{l}{A} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (iii)$$

Since $\rho$ and $A$ are constants then they can be replaced with a constant $k_3$ as shown in the formula below

$$R = k_3 l \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (iv)$$

Hence $R \propto l$............................................................................................................ $(v)$

Since underground cables cover long distances in **kilo**meters (km) then the resistors used to represent cables would also be in **kilo** Ohms (kΩ). Each phase is represented by a series of four 1 kΩ resistors as shown in the figure 28.

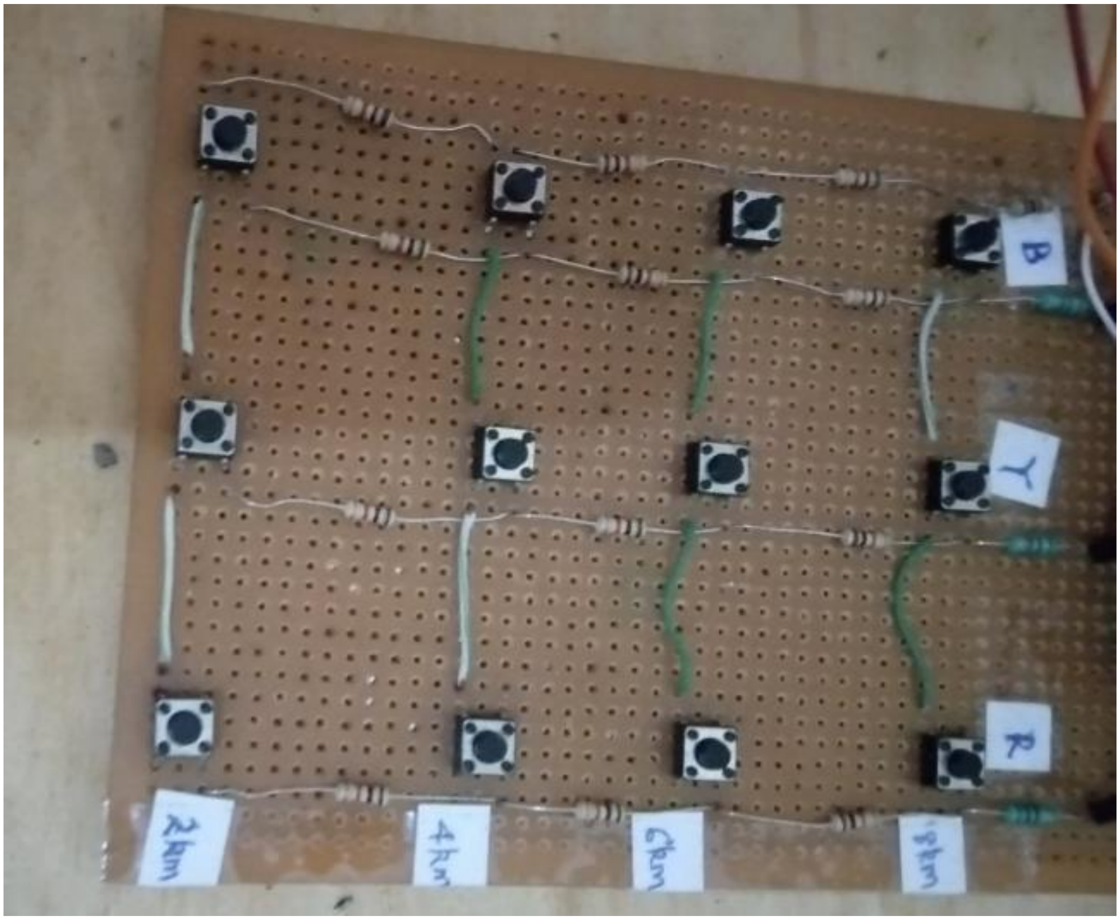


Figure 28: Positions of push buttons along each phase.

From equation (V), to represent a cable in each phase, four 1 kΩ resistors are connected in series and along each phase there are four push buttons each placed at a distance of 2 km from each other. These push buttons are used to simulate short circuit faults that is line to ground (LG), double line to ground (LLG), and all lines to ground (LLLG).

$$R = 1\ k\Omega + 1\ k\Omega + 1\ k\Omega + 1\ k\Omega = 4\ k\Omega$$

$$l = 2\ km + 2\ km + 2\ km + 2\ km = 8\ km$$

From equation $(iv)$, it gives, $R = k_3 l$

$$k_3 = 0.5\frac{k\Omega}{km} = 0.5\Omega/m$$

$$k_3 = \frac{\rho}{A} = 0.5\Omega/m$$

### 3.2.5 Simulation

Simulation is carried out using proteus. Both power supply and underground cable fault location and notification system circuits are simulated in proteus as shown in Figure 29.

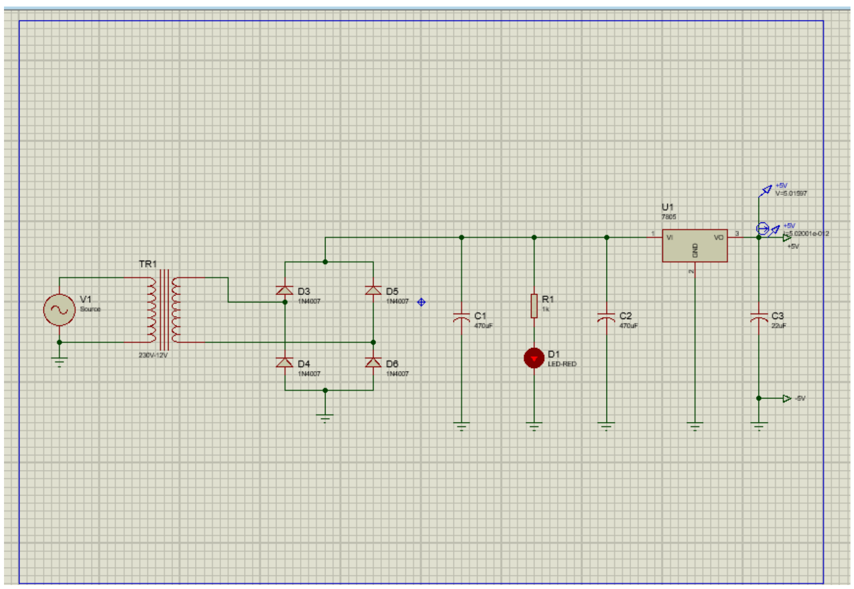


Figure 29: The screenshot of 5V power supply in proteus.

The figure 20 has four parts which include transformer, rectification, filtering and regulation. The transformer steps down a higher voltage say 230 V to a lower voltage 8 V. This voltage value of 8 V is fed to the rectifier that converts AC to DC which is suitable for DC components but the DC voltage obtained from the rectifier is not pure DC instead it is a pulsating DC so it is passed through the smoothing capacitor which filters out the ripples hence making it pure DC. This is called filtering process. To get the required constant output voltage that is 5 V, regulation is carried out through the voltage regulator IC.

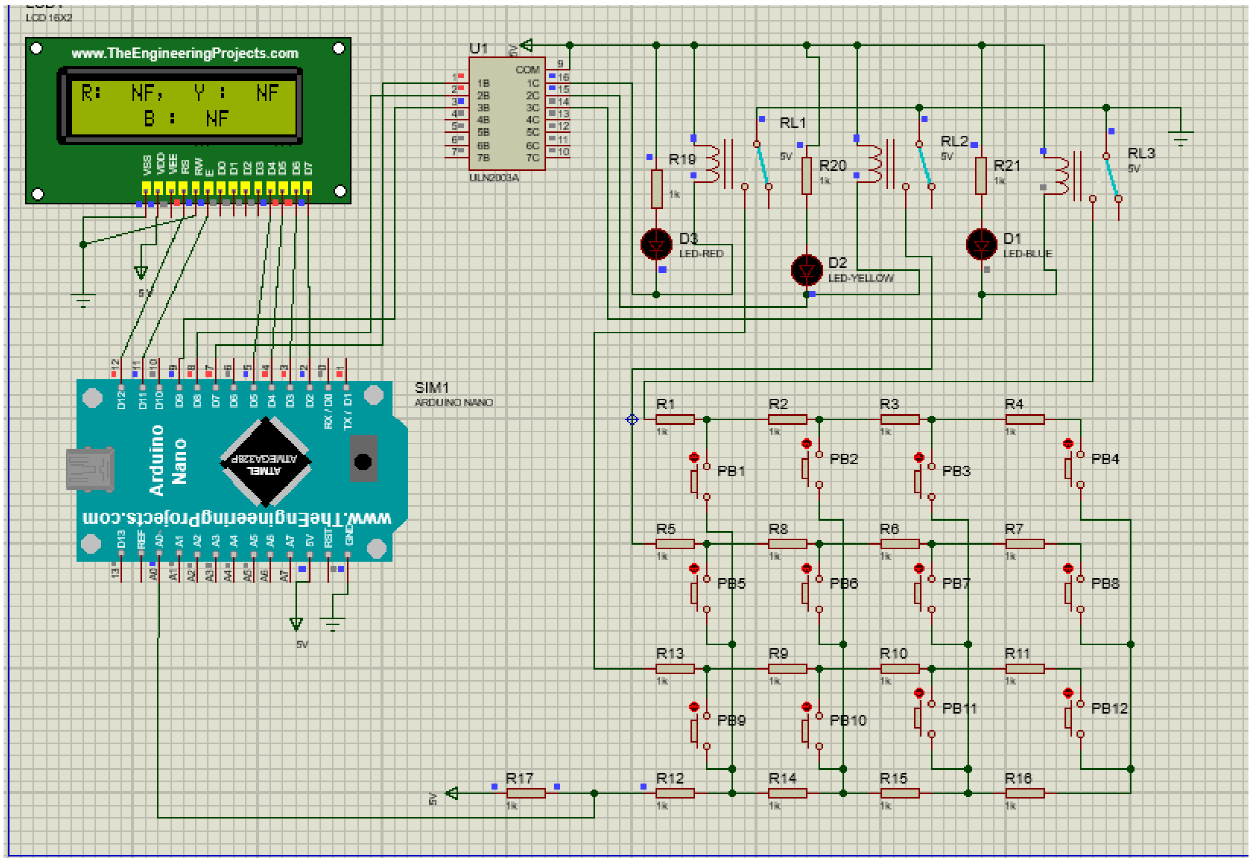


Figure 30: The screenshot of underground cable fault location and notification system

The figure 30 shows the display section, microcontroller, fault setup and controlling unit.

**Display section**

This section displays the fault location and its respective phase. The liquid crystal is the primary display device used. It has an I2C interface that has four pins namely SCL, GND, SDA and VCC.

**Microcontroller**

Arduino Nano is used as the microcontroller that reads inputs that is it reads analogue signal from the fault setup to locate of a fault point and this can be done through analogue and digital pins. Once the Arduino Nano decodes the signal, the location of the fault point is displayed on the liquid crystal display screen.

**Fault setup**

Cables have resistances, and thus will be represented by a group of four 1 k resistors connected in series. Cables even have resistance per kilometer ratings. These become terribly helpful when measuring for fault distances within the cable. Any deviations in resistance for a selected length indicates the presence of a fault within the cable. The series 1 kΩ resistors for voltage drop, divides each of the 3 cables into four sections where by every section represents 2 km. The relay closes for a particular phase when the short circuit fault has been activated. This sends a signal in order to determine the phase in which the fault occurred. This information is then displayed on the LCD screen. The fault setup contains of one resistors and switches whereby the resistors square measure connected asynchronous to represent a cable. From the figure thirty one, the series resistors R1, R2, R3 and R4 represent a RED part, the series resistors R5, R8, R6 and R7 represent a YELLOW part and at last the series resistors R13, R9, R10 and R11 represent a BLUE part.

**Controlling unit**

It has a relay module connected to the fault setup. It also monitors the phases by closing the Normally Open contacts when it finds the fault among the phases. The relay module has three different colored LEDs namely a red LED, yellow LED and blue LED for RED, YELLOW and BLUE phases respectively as shown in the figure 34. And the fault setup has push buttons which are used in creating a fault in each phase. For instance when one of the push buttons in a RED phase is closed, a fault is created and this happens at a distance in km which is indicated on the LCD. The red LED goes off due to a fault and if the line is healthy, NF is displayed on the LCD which means that the phase has no fault.

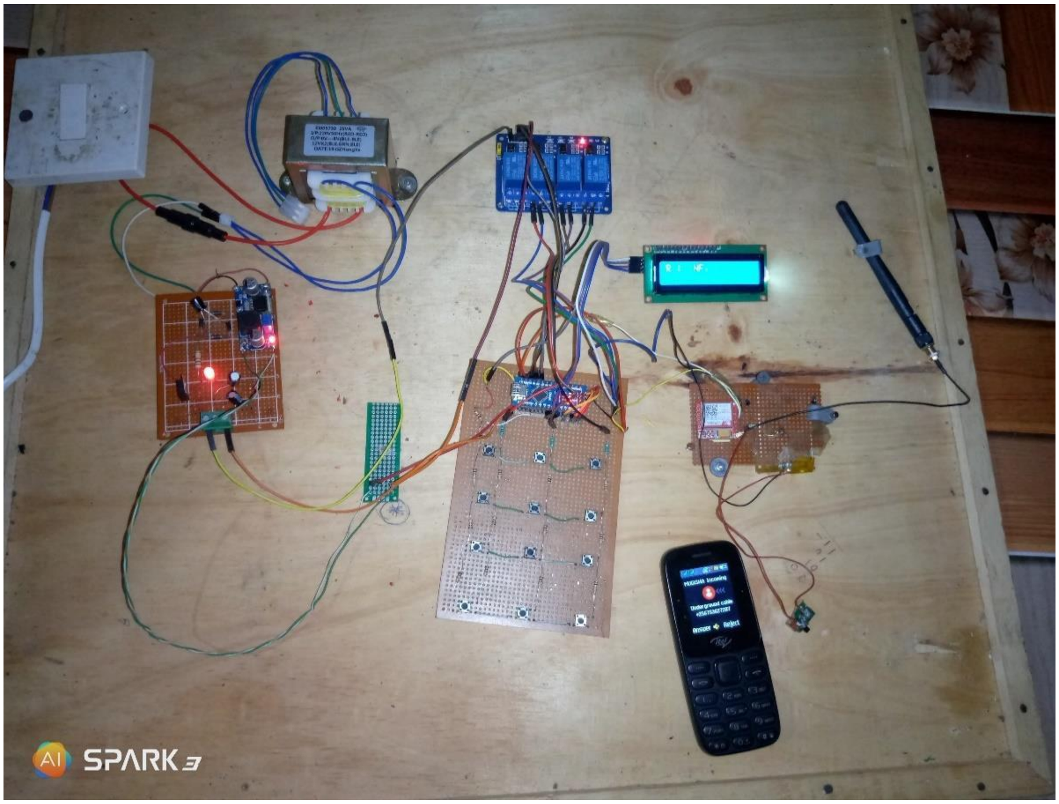

Figure 31: Complete working underground cable fault location and notification system circuit.

### 3.3 Notification system

The underground cable fault location and notification system uses GSM SIM800L. This GSM is powered by 4.2 V, 2 A for it to be connected to the network. This has its power supply and it sends a message and calls after location of the fault point in the underground cable. The GSM800L operates at frequency of 800 MHz.

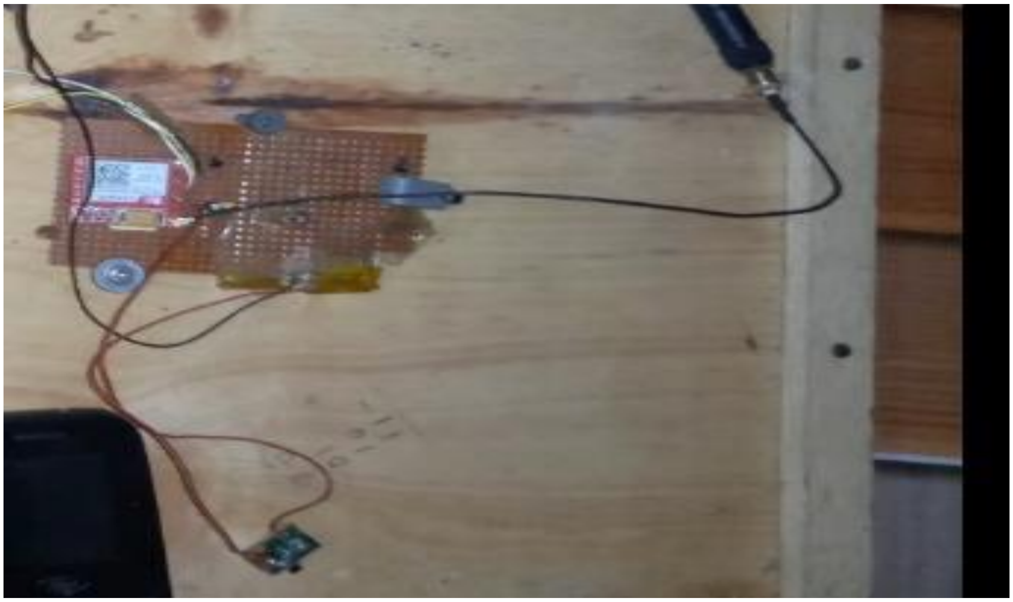

Figure 32: The GSM circuit

## 3.4 Components used

**Transformer**

This steps down voltage from 230 V to 8 V and the stepped down voltage is fed into the rectifier where rectification takes.


Figure 33: The step down transformer.

**A relay module**

This module consists of 4 relays but only 3 relays were used in this project for RED, YELLOW and BLUE phases.


Figure 34: The 5 V relay module

**Resistors**

The resistors used are 1 k. The four 1 k resistors were used to represent the length of the cable.

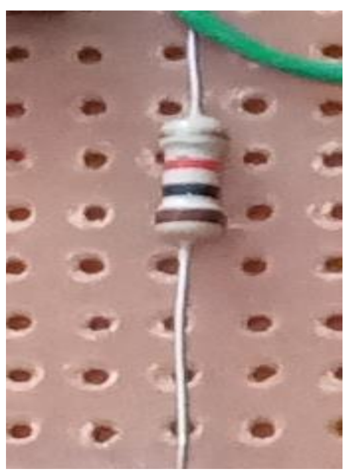

Figure 35: The 1 k resistor

**Liquid Crystal Display (LCD)**

This is a 16x2 LCD screen display with I2C interface. It's capable of showing 16x2 characters on a pair of lines, white characters on blue background. This I2C 16x2 Arduino LCD Screen is victimization associate degree I2C communication interface. It means that it solely desires four pins for the LCD display: VCC, GND, SDA, and SCL. It'll save a minimum of four digital/analog pins on Arduino.

Figure 36: The 16x2 LCD screen.

**Push buttons**

These are used in this project specially for simulating a fault in a phase

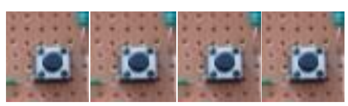

Figure 37: The push buttons.

## CHAPTER FOUR: RESULTS AND DISCUSSIONS

A CRO is connected across the output terminals of the bridge rectifier and it displays a non-straight line (yellow in color). Hence it signifies that the output voltage is not a pure DC instead it is containing AC ripples which need to be removed by connecting a smoothening capacitor.

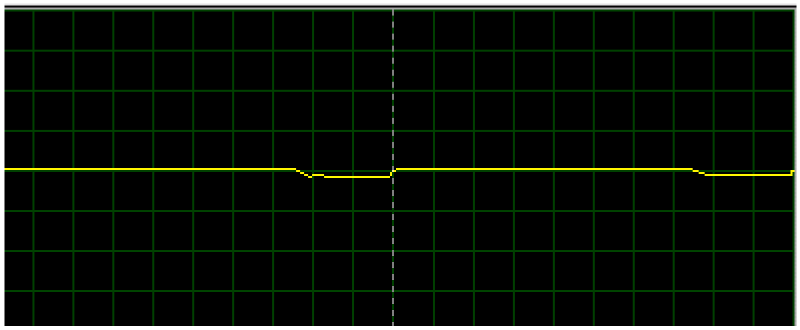

Figure 38: The varying output DC.

After connecting the smoothening capacitor and the voltage regulator across the output of the rectifier, a CRO is connected across the output terminals of the power supply and it displays a straight line (yellow in color). Hence it signifies that the output voltage is a constant DC.

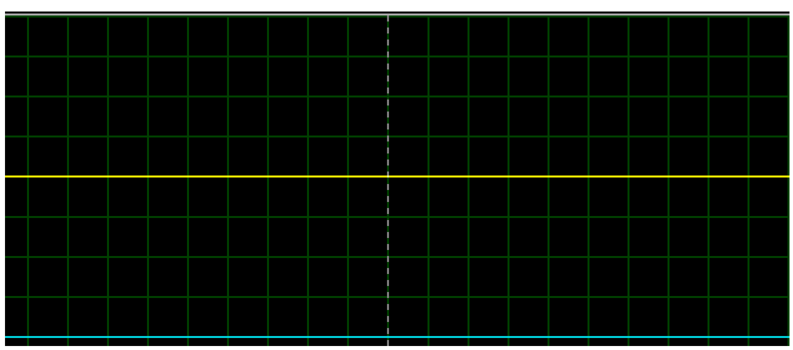

Figure 39: A CRO wave form of the output signal.

When a DC voltmeter is connected to the output terminals, it reads 5 V as an output voltage.

The wave form is fixed and constant indicated by the straight line as shown in the figure 39 above.

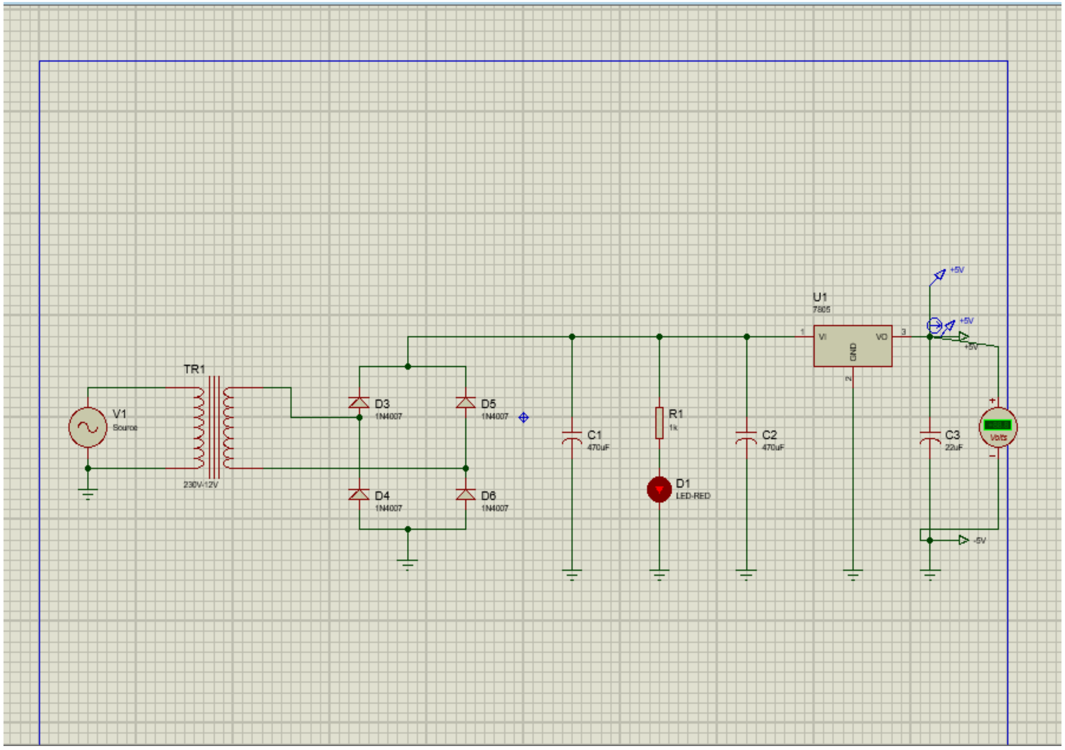


Figure 40: Measurement of output voltage.

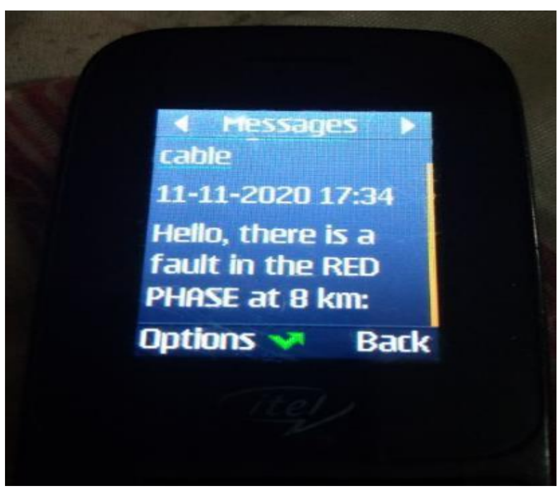


Figure 41: The message sent to the phone after location of a fault.

From proteus simulation, fault points were simulated at different switches which act as fault points as shown in the Table 2.

**Table 2: The fault voltages with their respective fault points**

| No | Push button(PB) closed | Voltage across series resistor(V) | Distance at which fault occurs(km) |
|---|---|---|---|
| 1 | PB 4 | 1.33 | 2 km of RED phase cable |
| 2 | PB 6 | 1.30 | 6 km of YELLOW phase cable |
| 3 | PB 11 | 1.71 | 4 km of BLUE phase cable |
| 4 | PB 4 and PB 6 | 2.40 | Between 2 km and 6 km of RED and YELLOW phase cables. |
| 5 | PB 7 and PB 12 | 2.40 | Between 4 km and 2 km of YELLOW and BLUE phase cables. |
| 6 | PB 3, PB 7 and PB 11 | 4.00 | 4 km of RED, YELLOW and BLUE phase cables |

**Table 3: Voltages and Currents in faulted cables.**

| Faulted cable | Voltage (V) | Current(A) |
|---|---|---|
| PB 4 | 1.33 | 0.0013 |
| PB 6 | 1.30 | 0.0012 |
| PB 11 | 1.71 | 0.0014 |
| PB 4 and PB 6 | 2.40 | 0.0024 |
| PB 7 and PB 12 | 2.40 | 0.0023 |
| PB 3, PB 7 and PB 11 | 4.00 | 0.0044 |

# CHAPTER FIVE: FUTURE WORKS AND CONCLUSION

## 5.1 Conclusion

The fault voltage and fault current in a single phase are less than those that occur in double phase and in all three phases. If the underground cable gets a fault in a single phase taking switch PB 4 at 2 km, smaller fault currents flow. If a fault occurs at distance between 2 km and 6 km taking switches PB 4 and PB 6 respectively, the high fault currents flow. If a fault occurs at distance 4 km taking switches PB 3, PB 7 and PB 11 respectively, the high fault currents flow. The fault in all phases is dangerous because large amount of fault currents flow within the power system hence underground cable fault location and notification system is required.

## 5.2 Future works

In this project, the fault due to short circuit is located in the underground cable from feeder end in km by using Arduino. The fault distance calculation is based only on cable resistance, in the future, this project can be implemented to calculate the impedance by using a capacitor in an AC circuit and thus this can be used in measurement of open circuit.

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# APPENDIX

## PROJECT SCHEDULES

### Table 4: The project schedules

| ACTIVITIES | AUG | SEPT | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | OCT | NOV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONCEPT NOTE DEVELOPMENT | | | | | | | | | | | | | | | |
| PROJECT TITLE | | | | | | | | | | | | | | | |
| DRAFTING PROPOSAL | | | | | | | | | | | | | | | |
| PROPOSAL PRESENTATION | | | | | | | | | | | | | | | |
| DATA COLLECTION | | | | | | | | | | | | | | | |
| DATA PROCESSING | | | | | | | | | | | | | | | |
| DATA ANALYSIS | | | | | | | | | | | | | | | |
| REPORT WRITING | | | | | | | | | | | | | | | |
| PROJECT REPORT PRESENTATION | | | | | | | | | | | | | | | |
| PROJECT REPORT SUBMISSION | | | | | | | | | | | | | | | |

## BUDGET

**Table 5: Shows components used in the project and their prices**

| Serial No. | Components | Qty | Unit price(UgShs) | Total price(UgShs) |
|---|---|---|---|---|
| 1 | Bread board | 1 | 13000 | 13000 |
| 2 | Jumper wires | A set | 25000 | 25000 |
| 3 | A 12 V transformer | 1 | 25000 | 25000 |
| 4 | GSM SIM 800L | 1 | 140000 | 140000 |
| 5 | Voltage regulator | 2 | 1500 | 3000 |
| 6 | Diodes | 10 | 1000 per 5 diodes | 2000 |
| 7 | Resistors | 21 | 3500 | 3500 |
| 8 | LEDs | 6 | 2000 | 2000 |
| 9 | Capacitors | 8 | 1500 | 1500 |
| 10 | Push switches | 14 | 4000 | 4000 |
| 11 | LCD display | 1 | 25000 | 25000 |
| 12 | Vero boards | 2 | 2000 | 2000 |
| 13 | Relays | 3 | 7000 | 21000 |
| 14 | Arduino | 1 | 60000 | 60000 |
| 15 | Transport | To and From | 40000 | 40000 |
| 16 | Miscellaneous | | 60000 | 60000 |
| | TOTAL | | | **429500** |

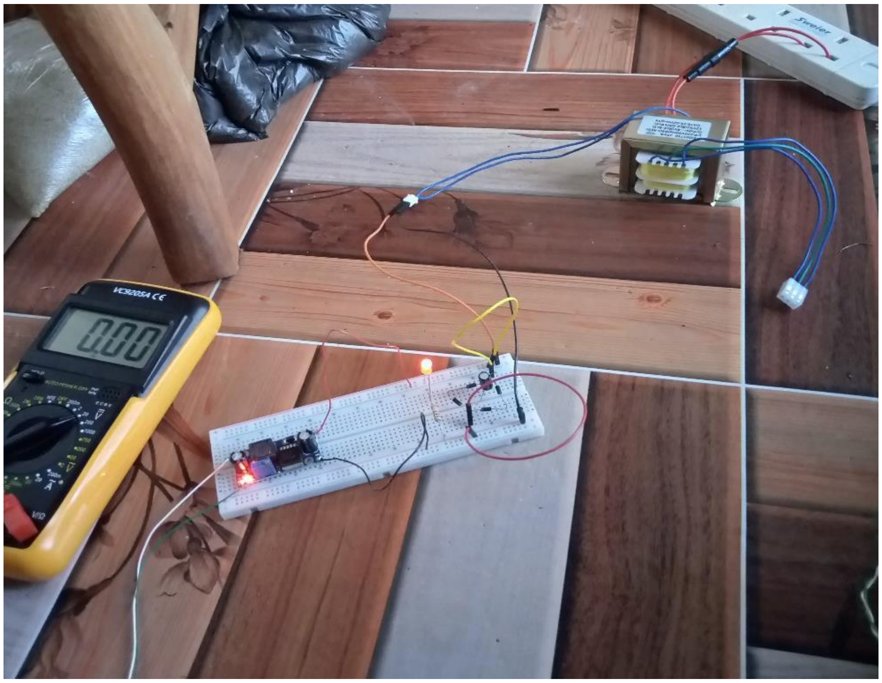

Figure 42: The 5 V power supply on the vero board

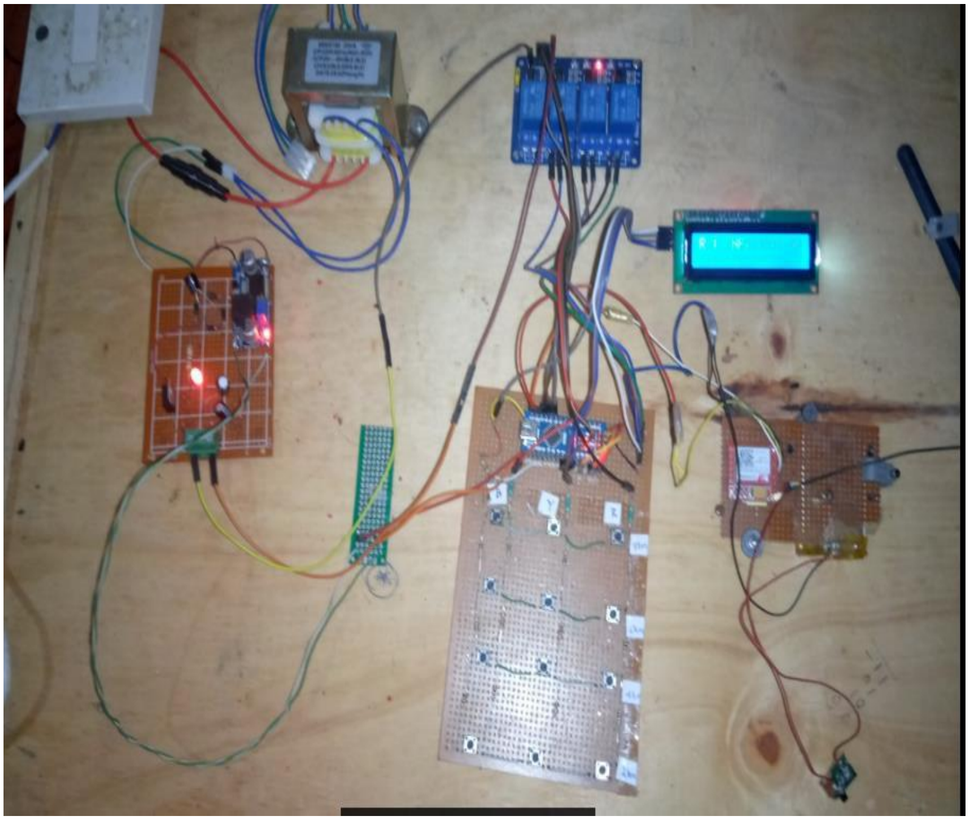

Figure 43: Complete system circuit

```
 // The Sample code of Underground Cable Fault Location and Notification Systems
#include <LiquidCrystal_I2C.h>

#include <SoftwareSerial.h>

SoftwareSerial sim(10, 11);

LiquidCrystal_I2C lcd(0x27,16,2);

char phone_no[] = "+256756476223"; //The phone no. to get sms

int _timeout;

String _buffer;

String textMessage;

const int sensorPin = A0;

int sensorValue;

String number = "+256756476223"; //-> The phone number in phone

String number1 = "+256753627287"; //-> The phone number in GSM

int red =0;

int yellow =0;

int blue =0;

void setup(){

  Serial.begin(9600);

  _buffer.reserve(50);

  Serial.println("System READY");

  sim.begin(9600);

  delay(5000);

 Serial.println(F("Type s to send an SMS, r to receive an SMS, and c to make a call"));

   sim.print("AT+CMGF=1\r"); //Sets the GSM Module in Text Mode

    delay(100);

    sim.println(F("AT+CNMI=2,2,0,0,0")); // AT Command to receive a live SMS

    delay(100);

delay(5000);

lcd.init();

lcd.backlight();

lcd.print("UNDERGROUND CABLE");

lcd.setCursor(0, 1);

lcd.print(" FAULT LOCATION ");

delay(1000);
```

```
delay(1000);
lcd.scrollDisplayLeft();
// wait a bit:
delay(2000);
lcd.clear();
lcd.print("AND NOTIFICATION SYSTEM");
lcd.setCursor(0, 1);
lcd.print("     SYSTEM     ");
delay(1000);
delay(1000);
pinMode(7, OUTPUT);
pinMode(8, OUTPUT);
pinMode(9, OUTPUT);
digitalWrite(7, LOW);
digitalWrite(8, HIGH);
digitalWrite(9, HIGH);
  Serial.println(F("System Starting..."));
  delay(7000); //delay for 7 seconds to make sure the modules get the signal
  }
  void loop(){
lcd.clear();
digitalWrite(7, LOW);
digitalWrite(8, HIGH);
digitalWrite(9, HIGH);
delay(350);
 sensorValue = analogRead(sensorPin); // read the value from the sensor
Serial.println(sensorValue); //prints the values coming from the sensor on the screen
    if(Serial.available() > 0 || sim.available() > 0 ){
    textMessage = sim.readString();
    Serial.print(textMessage);
    delay(10);
    delay (1500);
}
```

```
 if( (sensorValue >= 1000) )
{
lcd.setCursor(0, 0);
lcd.print(F("R : NF,")) ;//No fault in Red phase
Serial.println(F("R : NF,")) ;
red = 0;
 }
 else if(sensorValue >= 890 && sensorValue <= 920 )
{
   Serial.print(F("R : 2km,")) ;
lcd.setCursor(0, 0);
lcd.print(F("R : 2km,")) ;
   red = 2;
   red2km();
   delay(5000);
   callNumber();
   delay(1000);
}
 else if( sensorValue >= 870 && sensorValue <= 880 )
{
   Serial.print(F("R : 4km,")) ;
lcd.setCursor(0, 0);
lcd.print(F("R : 4km,")) ;
   red = 4;
   red4km ();
   delay(5000);
   callNumber();
   delay(1000);
}
 else if( sensorValue >= 800 && sensorValue <= 825 )
{
Serial.print(F("R : 6km,")) ;
lcd.setCursor(0, 0);
```

```
lcd.print(F("R : 6km,")) ;
red = 6;
red6km ();
delay(5000);
    callNumber();
    delay(1000);
}
    else if( sensorValue >= 670 && sensorValue <= 688 )
{
  Serial.print(F("R : 8km,")) ;
lcd.setCursor(0, 0);
lcd.print(F("R : 8km,")) ;
red = 8;
red8km ();
delay(5000);
    callNumber();
    delay(1000);
}
delay(1500);
digitalWrite(7, HIGH);
digitalWrite(8, LOW);
digitalWrite(9, HIGH);
delay(350);
  sensorValue = analogRead(sensorPin); // read the value from the sensor
Serial.println(sensorValue); //prints the values coming from the sensor on the screen
if( sensorValue >= 1000 )
{
Serial.println(F("Y : NF")) ;
lcd.setCursor(8, 0);
lcd.print(F(" Y : NF,")) ;
yellow = 0;
 }
 else if( (sensorValue >= 890) && (sensorValue <= 920) )
```

```
{
lcd.setCursor(8, 0);
Serial.print(F("Y : 2km,")) ;
lcd.print(F(" Y : 2km,")) ;
yellow = 2;
yellow2km ();
delay(5000);
   callNumber();
   delay(1000);
}
else if( (sensorValue >= 870) && (sensorValue <= 880) )
{
Serial.print(F("Y : 4km,")) ;
lcd.setCursor(8, 0);
lcd.print(F(" Y : 4km,")) ;
yellow = 4;
yellow4km ();
delay(5000);
   callNumber();
   delay(1000);
}
else if( (sensorValue >= 800) && (sensorValue <= 825) )
{
Serial.print(F("Y : 6km,")) ;
lcd.setCursor(8, 0);
lcd.print(F(" Y : 6km,")) ;
yellow = 6;
yellow6km ();
delay(5000);
   callNumber();
   delay(1000);
}
```

```
else if( (sensorValue >= 670) && (sensorValue <= 688) )
{
 Serial.print(F("Y : 8km,")) ;
lcd.setCursor(8, 0);
lcd.print(F(" Y : 8km,")) ;
yellow = 8;
yellow8km ();
delay(5000);
    callNumber();
    delay(1000);
}
 delay(1500);
digitalWrite(7, HIGH);
digitalWrite(8, HIGH);
digitalWrite(9, LOW);
delay(350);
sensorValue = analogRead(sensorPin); // read the value from the sensor
Serial.println(sensorValue); //prints the values coming from the sensor on the screen
if( sensorValue >= 1000 )
{
lcd.setCursor(5, 1);
Serial.println(F("B : NF")) ;
lcd.print(F("B : NF")) ;
blue = 0;
 }
 else if( sensorValue >= 890 && sensorValue <= 920 )
{
Serial.println(F("B : 2km")) ;
lcd.setCursor(5, 1);
lcd.print(F("B : 2km")) ;
blue = 2;
blue2km ();
delay(5000);
```

```
    callNumber();
    delay(1000);
}
else if( sensorValue >= 870 && sensorValue <= 880 )
{
Serial.println(F("B : 4km")) ;
lcd.setCursor(5, 1);
lcd.print(F("B : 4km")) ;
blue = 4;
blue4km ();
delay(5000);
    callNumber();
    delay(1000);
}
else if( sensorValue >= 800 && sensorValue <= 825 )
{
 Serial.println(F("B : 6km")) ;
lcd.setCursor(5, 1);
lcd.print(F("B : 6km")) ;
blue = 6;
blue6km ();
delay(5000);
    callNumber();
    delay(1000);
}
  else if( sensorValue >= 670 && sensorValue <= 688 )
{
Serial.println(F("B : 8km")) ;
lcd.setCursor(5, 1);
lcd.print(F("B : 8km")) ;
blue = 8;
blue8km ();
delay(5000);
```

```
    callNumber();
    delay(1000);
}
delay(1500);
  }
```