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MONITORING SYSTEM FOR DISTRIBUTION TRANSFORMER TEMPERATURE, LOAD CURRENTS AND VOLTAGE USING GSM

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ABSTRACT

In the electric power distribution system, a distribution transformer steps down the voltage used in distribution lines to the level used by the customer. furthermore, Transformers are one of the most critical components in distribution systems, but they are prone to a variety of faults and problems. As a result, real-time monitoring is considered a need for achieving an acceptable level of safety and dependability in operating power systems. This paper focuses on the design of a distribution transformer monitoring system that communicates using GSM technologies when abnormal operating conditions of the measured parameter are discovered. In the design, current transformers were used as current sensors, potential transformers were utilized as voltage sensors, and RTD was used as a temperature sensor. The system used an Arduino Uno to detect if these parameters were within normal working conditions, and if they weren't, the system sent an SMS to the operator through a GSM SIM900D. The main objective of developing this system is to reduce the likelihood of distribution transformer failures. Furthermore, because the transformers will not be subjected to abnormal operating circumstances for extended periods of time, their lifespan will be increased.

LIST OF ABBREVIATION

ADC: Analog to Digital Converter

GSM: Global System for Mobile Communications

SS: Sensory System

ES: Embedded System

SWER: Single Wire Earth Return

RS: Relative Saturation

DC: Direct current

AC: Alternating current

LCD: Liquid Crystal Display

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CHAPTER 1: INTRODUCTION

1.1. Design orientation

According [1], A transformer is an electrical device that convert AC power from voltage level to another voltage level through the action of a magnetic field without changing the frequency which consists of two or more coils of wire wrapped around a common ferromagnetic core and are not directly connected. The only connection between the coils is the common magnetic flux present within the core. One of the transformer windings is connected to a source of AC power, while the second transformer winding supplies electric power to loads. The transformer winding connected to the power source is called the primary winding or input winding, and the winding connected to the loads is called the secondary winding or output winding [1].

As stated by [2], there are various types of transformers, including Isolation Transformer where voltage levels are not converted as primary voltage and secondary voltage are always the same. This is due to the fact that the primary and secondary winding ratios are always equal which indicates the primary and secondary windings have the same number of turns[2].

According to [2], the isolation transformer is used to separate the primary and secondary windings, as well as to act as an isolation barrier where only magnetic flux is used for conduction and it is utilized for safety and to prevent noise from transferring from primary to secondary or vice versa. Another type of transformer is the ferrite core transformer which uses a ferrite core due to its high magnetic permeability. [2] claimed that in a high-frequency application, this type of transformer has very low losses. As a result, ferrite core transformers are employed in high-frequency applications including switch mode power supplies (SMPS), RF applications, and so on. According to [3] Transformers are one of the most important components in the distribution systems, however, they are susceptible to a variety of faults and issues. Therefore, Real-time monitoring is regarded a necessary prerequisite for achieving an acceptable degree of safety and dependability in running electricity systems.

this report shall concentrate on distribution transformers. A distribution transformer also known as a service transformer as a transformer that provides the final voltage transformation in the electric power distribution system (Electrical Grids) which steps down the voltage used in the distribution lines to the level used by the customer [4]. While according to [5], GSM (Global System for Mobile communication) is a digital mobile network that is widely used by mobile phone users all around the world which provides the user with wireless mobile telecommunications.

1.2. Problem statement

Most Namibian Electrical distribution companies do not have a monitoring system with GSM notification for distribution transformer which increases the likelihood of faults occurring in transformers hence reducing the transformer lifespan. Furthermore, due to the large amount of transformers in the distribution system, in most distribution company’s maintenance and check manually on a periodic basis, the maintenance schedule is sometimes not ahead to while other side some transformers might experience abnormalities/abnormal operating conditions before the maintenance check-up therefore it is important to design a system that will monitor transformers.

1.3. Design objectives

1. To measure the following parameters of the transformer:
   - Temperature
   - load currents of each phase
   - voltage of each phase
2. To analyse the above parameters and determine if they are in the normal range.
3. To communicate with the operator if any abnormality is detected in the system.

1.4. Design requirements

1.4.1. Functional requirements

The following functional requirements were intended to be met by the system:

- Sense load current, Voltage and temperature of the transformer.
- Analyse these parameters and determine if the parameters are in the normal range.
- If any abnormalities are detected the system will inform the operator using GSM technology.
- The system shall be powered by tapping from the LV line of the transformer.

1.4.2. Non-functional requirements

The following non-functional requirements were intended to be met by the system:

- User friendliness: the system should be easy to use.
- The system should be durable.
- The system should be cost-effective.

1.5. Design significance

This project's intent to lessen the likelihood of distribution transformer faults. Furthermore, because the transformers will not be running in abnormal conditions for long periods of time, the lifespan of the transformers will be extended.

1.6. Delimitations of the design

The design is based on a three-phase distribution transformer with a capacity of 100kVA and a voltage of 33kV/400V and the transformer’s nameplate is given appendix A. On that transformer, the calculations and size of components (sensors) were done.

1.7. System design

The hardware design and the software design are the two parts of the design. From the actual design, a prototype was created.

1.7.1. Hardware design

The prime objective was to size and select the optimal components for this project. Using these components, a physical product was designed using simulations software Proteus and a scale down prototype was assembled.

1.7.2. Software design

The primary objective of the software design was to create a program that could activate the sensors and operate the entire system. The figure 1 displays the system flowchart that shall be used in the development of the program.

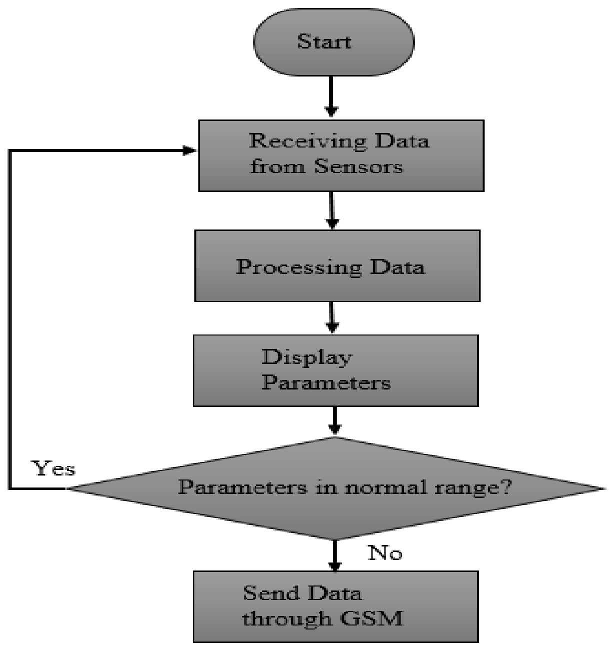

Figure 1: System Flowchart.

CHAPTER 2: LITERATURE REVIEW

2.1. Abnormal conditions found in distribution transformers

2.1.1. Thermal

As stated by [6], in electrical energy supply networks, high and intermediate voltage transformers are very significant components and made with a nominal life expectancy in years, and they're tested for a rated load under ideal conditions, as specified on the nameplate. The oil temperature and the hot-spot temperature of the transformer windings, which are directly impacted by the following and are the key parameters that determine the transformer's life:

losses in the winding and core

According to [7], Due to losses in the winding and core, which are passed to the insulating oil, the temperature of the transformer rises. The transformer may fail prematurely if these temperature rises exceed the insulation and core materials' thermal capacities.

Oil level

According to [8], the major purposes of transformer oil are to insulate and cool a transformer. Therefore Low oil levels increases the transformer temperature as it can expose energized and current-carrying components that are designed to work in oil, resulting in overheating or an electrical flashover [9].

Loading

[10] stated that when a transformer is subjected to voltages and/or currents that exceed its design parameters, it is said to be overloaded. Excess heat caused by overloading will cause the transformer's insulation system to fail, reducing the transformer's life expectancy.

2.1.2. Overloading

According to [11], when at least one of the phase currents exceeds its rated value, overloading can occur. Overloading in distribution transformers is a complex problem (an important tissue) that necessitates a comprehensive understanding of load behavior, transformer effective parameters, and environmental variables. Because the load variance in a distribution system is significantly greater than in a transfer system, one phase may be overloaded for a longer period of time. Long-term overloading that exceeds the standard length causes substantial harm to the transformer and shortens its life. Because the value and duration of transformer overloading are so important, we can use the following standards to determine permissible values. The approximate value of the overloading peak that a transformer can withstand without affecting its life time has been shown in accordance with the ANSI standard. The ambient temperature is supposed to be 30 degrees. However, each degree of temperature rises above 30 reduces the loading capacity by 1.5 percent. In addition, by lowering the temperature by one degree, it will increase by 1% [11].

[12] stated that Prolonged overloading, which can be caused by power theft is the main cause of failure of distribution transformers where [13] stated that Electrical disturbances and Overloading where the causes of above 29.43% for failure of Distribution Transformers, as during these

conditions [14] stated that the transformer heats up due to the access current and gradually weaken the insulation system through thermal degradation which causes cracks in the insulation. According to [15] a transformer will be considered to be overloaded if the secondary current is 125% of the rated current.

2.1.3. Unbalance Voltage

According to [11]The term "voltage unbalance" refers to a scenario in which the three phase voltages fluctuate in amplitude or are displaced from their typical 120-degree phase connection, or both. Power and distribution systems, particularly those with a large number of single-phase users, will experience voltage unbalance [11]. Taking into account the major impact of voltage imbalance on transformer lifetime and system reliability.

If the unbalanced load which is caused by the load imperfections cause current unbalance which travel to transformer and cause unbalance in the three phase voltage, occurs continuously on the transformer will decrease the transformer's performance [16].

According to [17] unbalanced Voltage always causes extra power loss in the system as the imbalance of current will increase the I2R Losses.

2.2. Monitoring system for distribution transformers

The present approach used by electrical distribution firms in Northern Namibia for monitoring distribution transformers is a manual check-up once every six months, but there have been projects aimed at remotely monitoring transformers such as [18]. The project's objective was to protect the distribution transformer or any other power transformer from catching fire due to an overload, where the project used a PT to monitor voltage and an LM35 to monitor temperature and deliver a warning to the operator through an SMS if abnormal conditions were observed. Furthermore, another project [19], which designed a monitoring system which monitored the transformer temperature, load, oil level hhumming noise. Both projects used an LM35 for measuring temperature and according to [19], LM35 is less accurate compared to sensor which one can place inside the transformer.

CHAPTER 3: DESIGN APPROACH

3.1. Design Structure

The design will be based on a 100KVA 33KV/400V 3 phase distribution transformer which shown in figure 2.

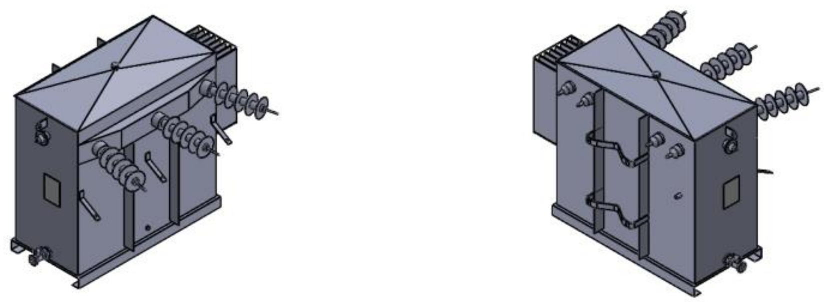

Figure 2: Transformer.

3.1.1. Functional Block Diagram

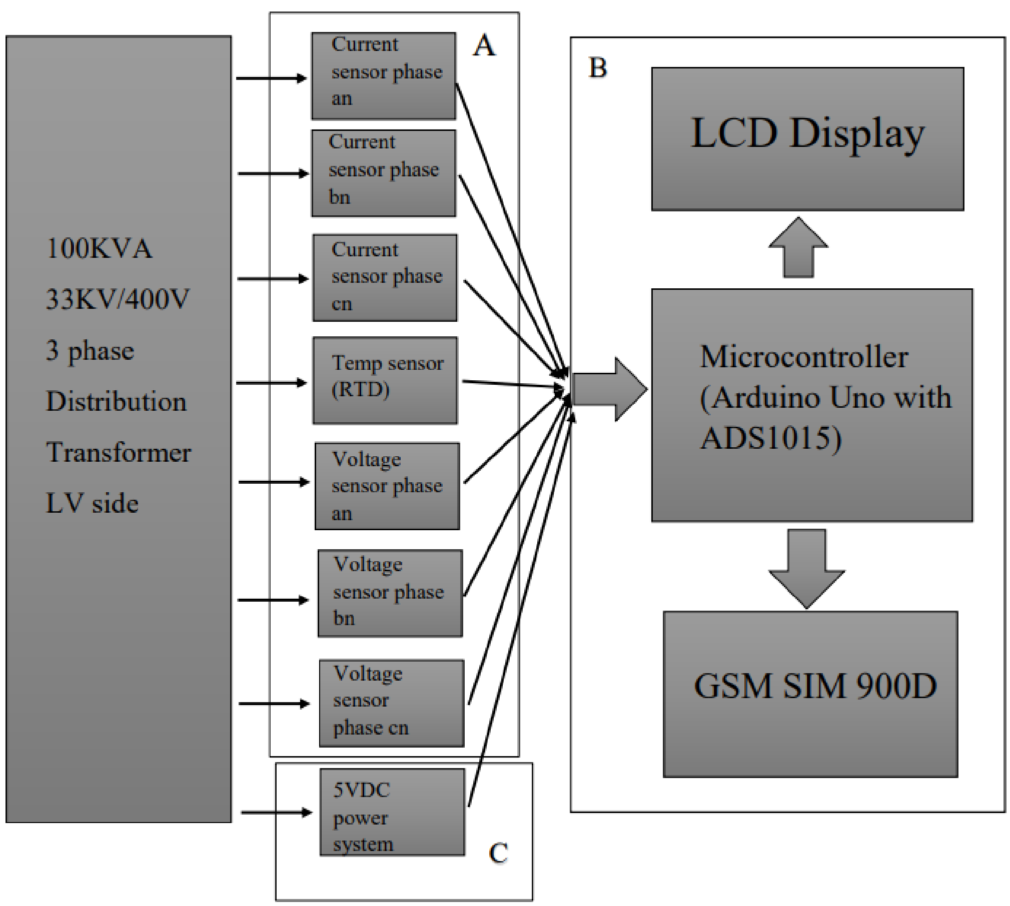

Figure 3: System Block diagram

Figure 3 illustrates the block diagram of the designed system. Appendices C-1, C-2, and C-3 depict the physical system's appearance.

The system is composed of three systems:

- **Sensory System (A)**

  The SS contain of sensors which are attached to the transformer used to sense/obtain the following parameters:

1. Transformer temperature
2. Load current
3. Voltages

- **Embedded system (B)**

  Once the sensors have sent the transformer data to the embedded system, the embedded system which has a microprocessor/microcontroller as an integral part of system which processes that data. Once the data is process the microcontroller then send a message using GSM if any abnormalities are detected.

- **Power system (C)**

  Figure 4 is a block representation of the physical system's power system.

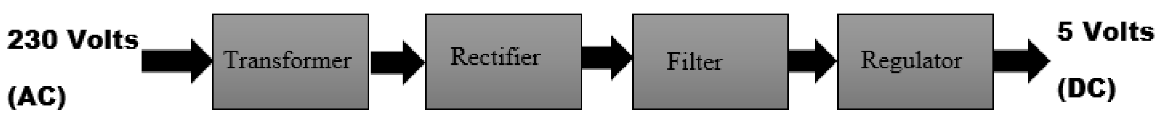

Figure 4:Power System.

- The transformer steps down the 230V AC to 5V AC.
- The rectifier then converts AC to DC, however the DC output is varying.
- The filter then smoothens the DC from varying greatly to a small ripple.
- Regulator then eliminates ripple by setting DC output to a fixed voltage.

3.2. Design instruments

- Proteus 8 professional software –simulation of system.
- Arduino IDE software – writing and uploading codes to Arduino boards and the Proteus 8 professional software.
- SolidWorks 2020 – designing the system's 3-D mechanical.

3.3. Design procedures

Figure 5 depicts a diagram of the methods to be used during the system design.

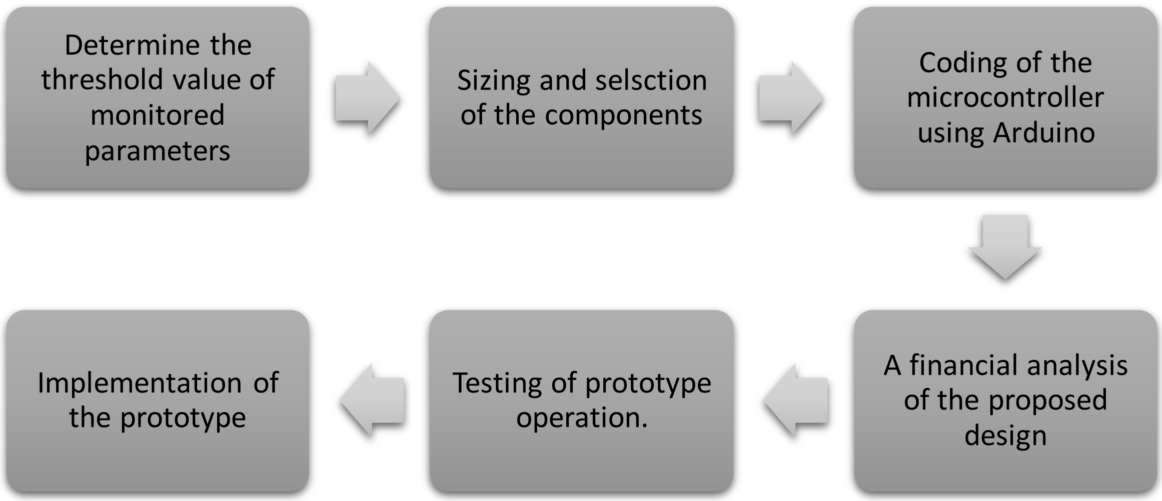

Figure 5: Procedures to be followed for the design project.

3.4. Design requirement

3.4.1. Design Components

3.4.1.1. sensory system

- ***Load Current***

The current sensor technology that shall be used for the design will be a current transformer.

Current threshold = rated current $\times$ 105%

= 144A$\times$ 105%

= 151.2A

CT ratio calculation

Secondary current = 144A

With Margin of 20%

CT current on the primary side

= 144A $\times$ 1.20

= 172.8A

= 172.8: 1 A $\approx \mathbf{200:1}\boldsymbol{A}$

Current transformer

Figure 6: current transformer

The current sensor will be a CM-CT 200/1 Current transformer 2.5VA, class 1 as indicated in figure 6.

- ***Voltage***

Voltage threshold

According to [11], NEMA definition of voltage unbalance also known as the line voltage unbalance rate (LVUR), is given by:

$$\%\mathrm{LVUR} = \frac{\mathrm{Max}\ (|V_{an} - 230\mathrm{V}|, |V_{bn} - 230\mathrm{V}|, |V_{cn} - \ 230\mathrm{V}|) \ \ \times * 100}{230\mathrm{V}}$$

Where 230V is the rated phase voltage of the transformer.

where $V_{an},\ V_{bn}$ and V_{cn} are phase voltages.

%LVUR should not exceed 5%.

Voltage sensor

Electrical power networks are typically operated at dangerously high voltages. Connecting panel-mounted instruments directly to the conductors of a power system when the voltage exceeds several hundred volts is both impracticable and unsafe. We must use a specific type of step-down transformer known as a potential transformer to decrease and isolate the high line voltage of a power system to levels safe for panel-mounted equipment to input. As a result, a 6V AC, 2 Output Through Hole PCB Transformer, 13VA, as indicated in figure 7 and table 1, will be employed.

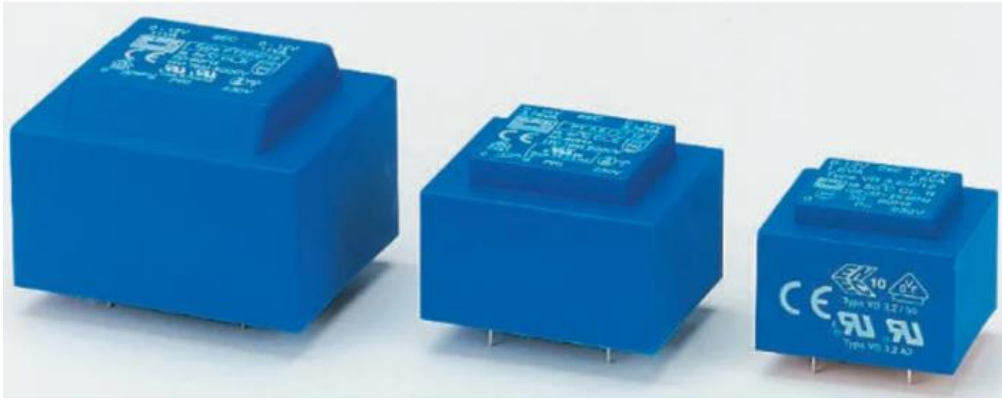

Figure 7:PT to be used

Table 1: PT specifications

Attribute	**Value**
Secondary Voltage Rating	6V ac
Power Rating	13VA
Primary Voltage Rating	230V ac
Number of Outputs	2
Dimensions	56 x 47 x 40mm
Weight	420g
Mounting Type	Through Hole
Maximum Temperature	+40°C

- ***Temperature***

Temperature threshold

TYPE TEST : MAX. TEMPERATURE RISE		
OIL	HV	LV
≤ 60	≤ 65	≤ 65

Figure 8: According to the datasheet

The winding temperature should not exceed **65°C**, while the oil temperature should not exceed **65°C**, according to figure 8 from the 100KVA transformer datasheet [20].

For temperature the sensor technology that shall be used for the design will be Resistance Temperature Detectors, as shown in tables 2, thermistor operates at low temperatures, making it unsuitable for use in a monitoring system. Thermocouples, on the other hand, are less accurate than RTDs as shown in table 3.

Table 2: RTD vs Thermocouples

RTD	Thermocouples
They are used for low temperature applications of up to 850°C for industrial RTDs	hey are used for high temperature applications of up to 1700°C s)
They are more accurate and stable than thermocouples	They are less accurate and stable than RTDs
They are expensive than thermocouples	They are very cheap compared to RTDs
They are not suitable for high vibration and mechanical shock environment	They are well suited for environment where high vibration and mechanical shock is present

Table 3: RTD vs Thermistors

Parameter	RTD	Thermistor
Response time	Slow (about 1 to 50 s)	Fast (about 0.12 to 10 s)
Temperature range	Large (between -100 to 650°C)	Small (between -15 to 60°C)
Sensitivity	Low	High
Cost	High	Low
Size	Large	Small
Accuracy	RTD generates less accurate results	Thermistor produces highly accurate results.
Recalibration	Easy	Its recalibration is somewhat tough as compared to RTD
Applications	It is widely used in industrial applications	It is widely used in home appliances

PT100

A platinum resistance temperature detector (RTD) PT100, according to [21], is a device that has a typical resistance of 100 at 0 ºC and belongs to the passive (parametric) sensor class. As the temperature varies, it alters its own resistance value in a positive slope (resistance is increasing with temperature increasing). External supply is required to measure those resistance fluctuations. Therefore, RS PRO 3 wire PT100 Sensor shall be used as shown in figure 9 and table 4 shown the RTD PT100 specifications.

Figure 9: RTD PT100

Features

Table 4: RTD PT100.

Sensor Type	PT100
Probe Material	Stainless Steel
Number Of Wires 3	3
Accuracy	Class B
Ice point resistance	100Ω
Fundamental interval (0°C to 100°C)	0.385Ω (per degree)
Minimum Temperature Sensed	-50°C
Maximum Temperature Sensed	250°C

3.4.1.2. The Embedded System

- The Arduino Uno which is shown in figure10 was employed as the system's control unit. It processes all of the system's inputs and outputs, as well as making all of the system's decisions.

Figure 10: Arduino Uno

- Figure 11 shows an ADS1015 which was utilized to add the number of ADC input pins.

Figure 11: ADS1015

- The I2C LCD display shown in Figure 12 will be utilized to display the measured parameters.

Figure 12: LCD display

- ❖ The GSM SIM 900D as shown in figure 13 was utilized as the system's and operator's communication channel. It was used to alert the operator if any irregularities in the measured parameters were discovered.

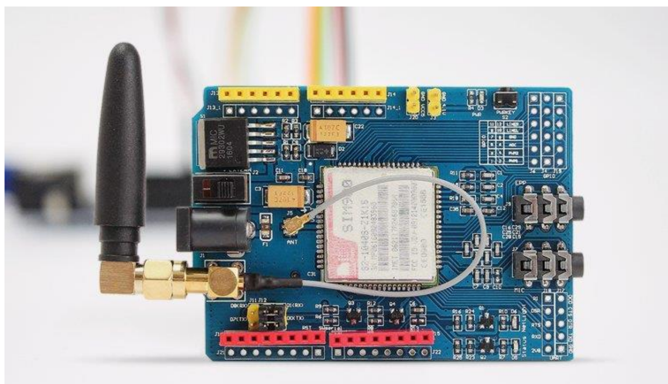

Figure 13: GSM SIM 900D

3.4.1.3. Power system

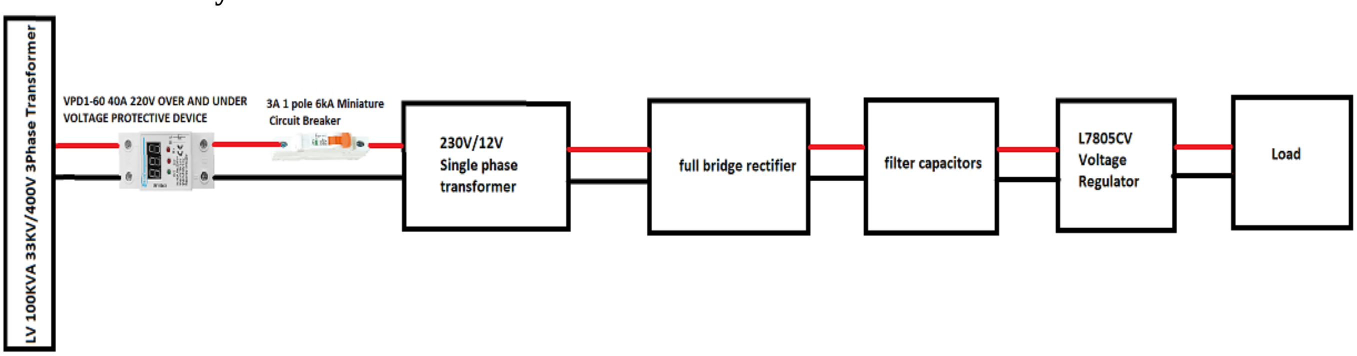

Figure 14:Power system

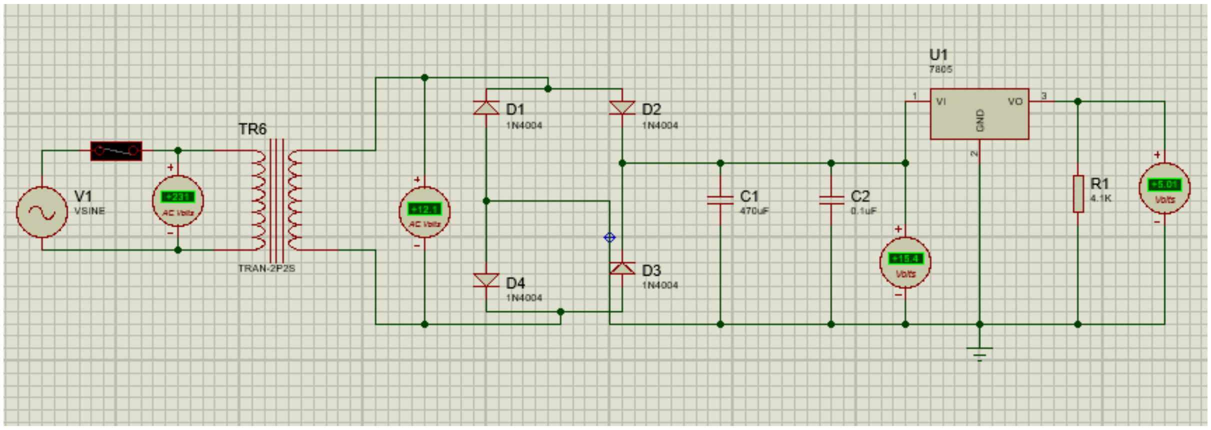

Figure 15: Power system simulation

To power the planned system, AC power must be drawn from the transformer's secondary lines, as shown in figures 14 and 15.

Power system protection

CB will be utilized as an overcurrent protection device to safeguard the system from overcurrent.

CB size = $System\ Ampere \times 125\%$

= $2A \times 125\%$

= 2.5A

As a result, illustrated in figure 16, a 3A CB should be employed.

Figure 16: 3A 1 pole 6kA Miniature Circuit Breaker.

A relay which is shown in figure 17 shall be used as overvoltage and under voltage protection device which will trip if the voltage drops below 170V and 275V.

Figure 17:40A 220V Automatic reconnect over voltage and under voltage protective device

Specifications:

- Name: 40A 220V Automatic reconnect over voltage and under voltage protective device
- Model: VPD1-60 40A
- Material: Plastic
- Color: White
- Size: 3.7cm x 8.5cm x 6.6cm/ 1.5" x 3.4" x 2.6"
- Rated voltage: 220V
- Rated current: 40A
- Overvoltage protection: ≥275V±5V
- Under-voltage protection: ≤170V±5V
- Recovery time: 25s

Stepdown of voltage

Since the voltage regulator Vin range from 10 V to 35 V, thus single phase 230V/12V transformer shall be used to step down the voltage.

AC/DC conversion

A full bridge rectifier shall be used to convert the AC power into DC (using 4×1N4004 diodes).

Filtering and regulating

A $1000\mu F$ Capacitors will be used as filters.

An L78S05CV voltage regulator will be used to regulate the output voltage to 5VDC.

2A

Product Information

Manufacturer Part No	L78S05CV
Input Voltage Min:	10V
Input Voltage Max:	35V
Product Range:	7805 Voltage Regulators
Output Current:	2A

Figure 18:L78S05CV

The L78S05CV specifications are shown in Figure 18.

3.5. Design system model

3.5.1. Hardware

The system circuit/model built in Proteus software is depicted in the figure 19:

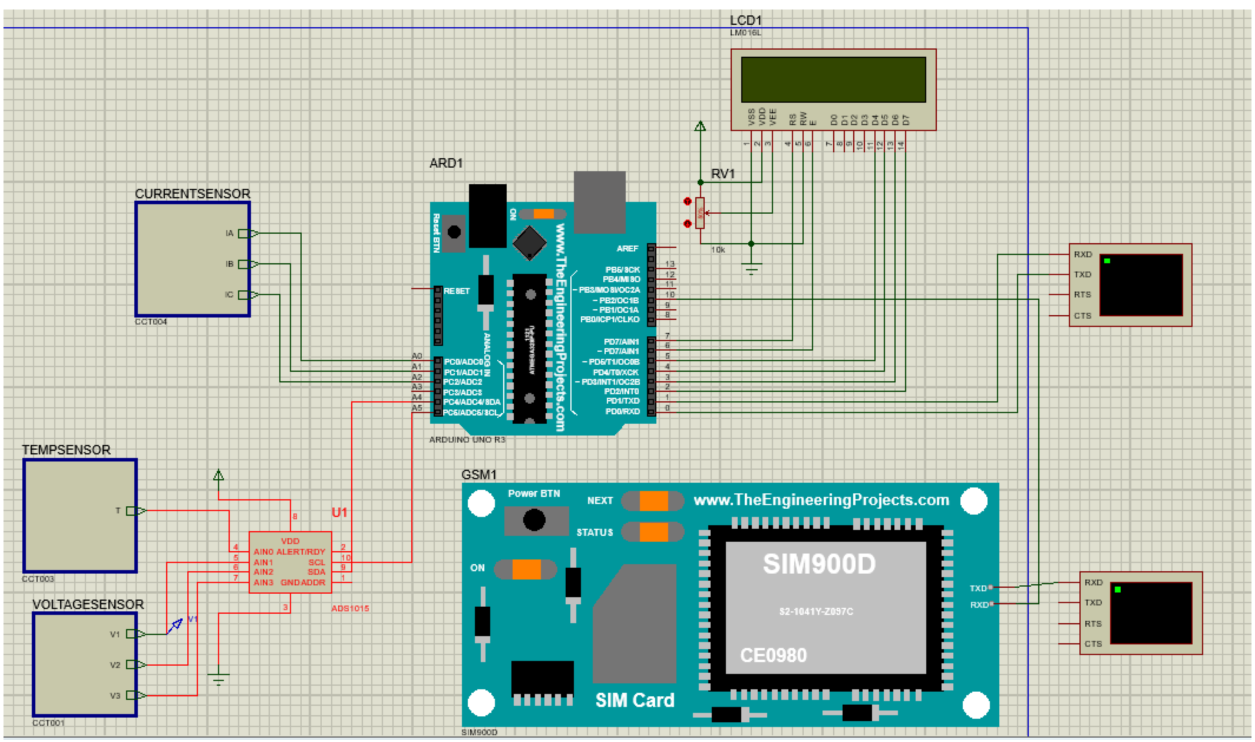

Figure 19: Main Design schematic Diagram.

The sensor for the parameter will not be connected directly to the Arduino because its output must be converted to DC voltage with a maximum value of 5V. The sensing circuits are shown in the diagrams below.

- **Current sensor circuit**

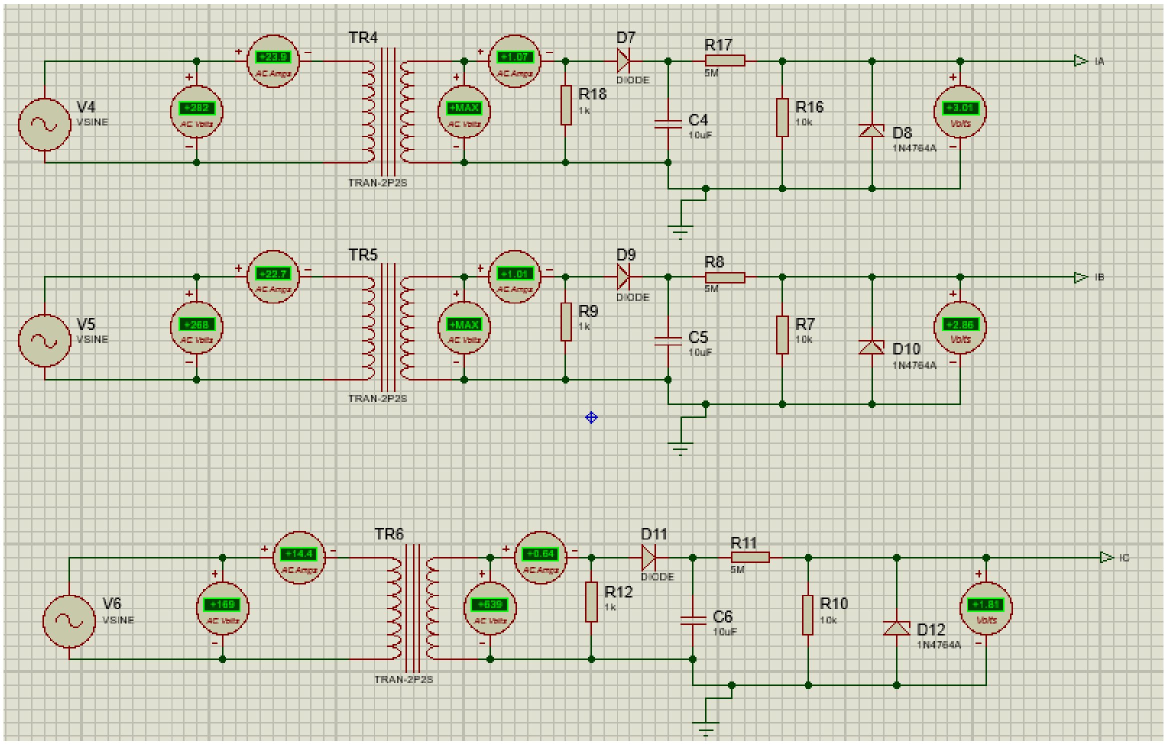

Figure 20: current sensor circuit

Because the Arduino Uno input voltage should be less than 5VDC. A 200:1A CT transformer was and connected in parallel to a burden resistor. A diode is than connected to convert the AC voltage to DC and capacitors are used to filter the voltage. Figure 20 display the current sensor circuit.

All three of the V_{out} will be direct connected to the Arduino pin A0 and A2.

The relationship between the input Voltage of the sensor and the output voltage is give as follow.

$I_{in} = V_{out} \times 58$

- **Temperature sensor Circuit**

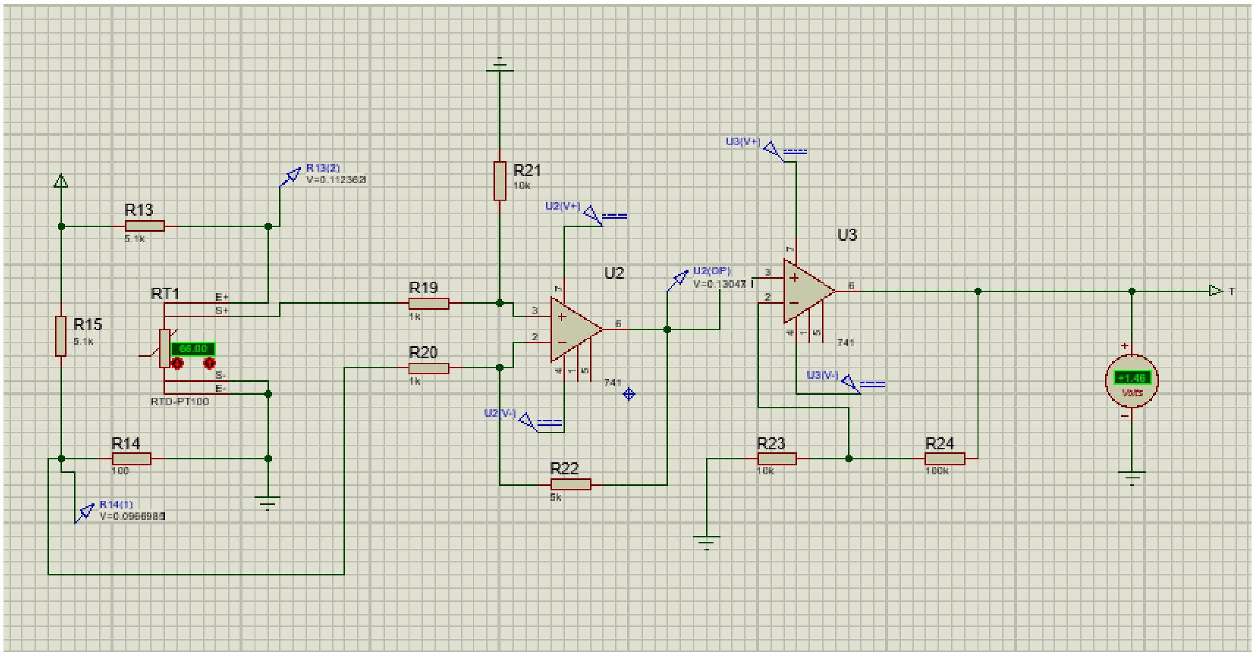

Figure 21:Temperature sensor Circuit

In the code the output voltage should not exceed 1.87 Volts as this Voltage indicates that the RTD temperature is 65°C which is the thresh hold temperature for the respective transformer. Figure 21 display the temperature sensor circuit.

- **Voltage sensor Circuit**

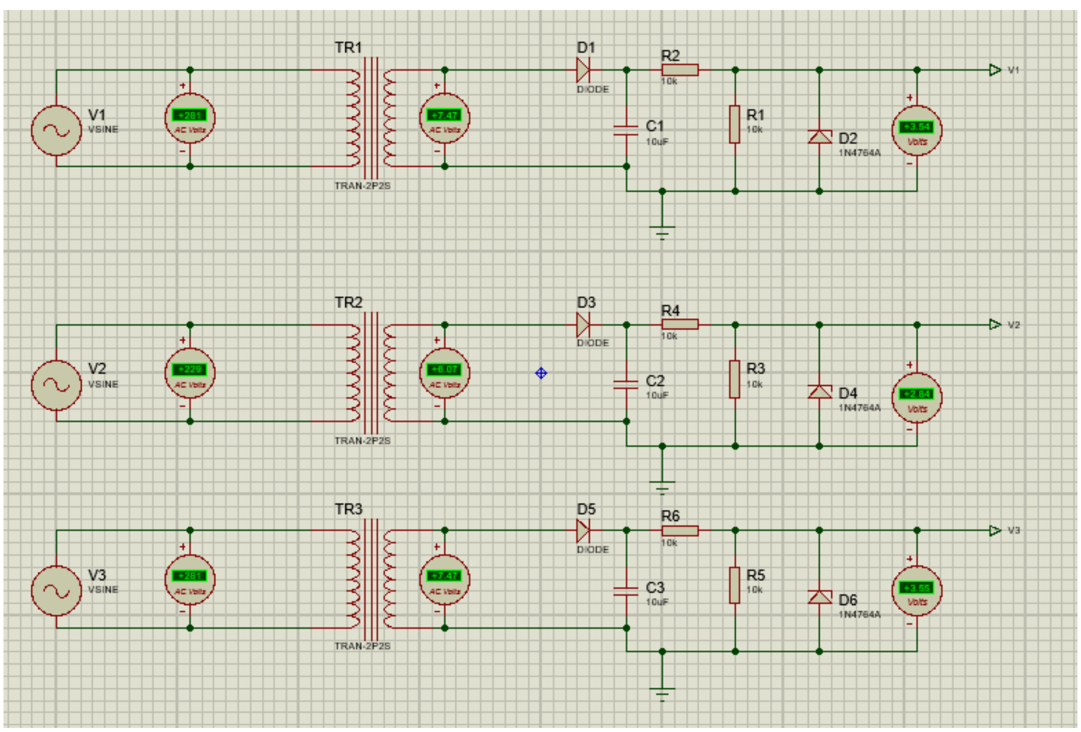

Figure 22:Voltage sensor Circuit

Because the Arduino Uno input voltage should be less than 5VDC. The voltage is stepped down using a 230V/6V transformer. A diode is than connected to convert the AC voltage to DC and capacitors are used to filter the voltage.

All three of the V_{out} will be direct connected to on the which is an ADC and it shall be connected on the Arduino pin A4 and A5. Figure 22 display the voltage sensor circuit.

The relationship between the input Voltage of the sensor and the output voltage is give as follow:

$V_{in} = V_{out} \times 83$

3.5.2. Software

The design work for the program that will be executed by the control unit, i.e. the ATmega328 microcontroller, where the system flow chart is displayed in figure 23. The primary program is made up of two programs that run in order: one that measures the parameters and displays them, and the other that sends a message to the operator. In the appendix B, one can find the source code that was coded in Arduino Ide.

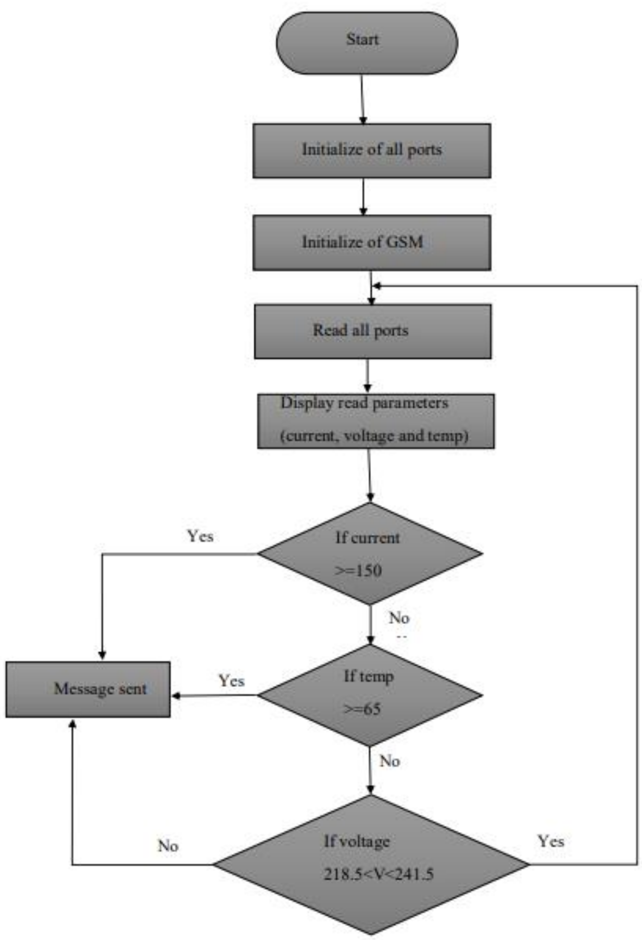

Figure 23: System flowchart.

3.6. Bill of quantities

Only the electrical components required for the physical monitoring system were covered in the table 5. The prices listed in this bill of quantities are the cheapest real-world prices for the components. The system's casing and material will be determined by the designer thus they are not included in the Bill of quantity.

Table 5: System bill of quantity

Item	**Quantity**	**Cost**	**Total cost**
230V/6V transformer	1	N$ 200	N$ 200
Current transformer	1	N$ 520	N$ 520
RTD PT100	1	N$ 2000	N$ 2000
Arduino Uno	1	N$ 145	N$ 145
LCD	1	N$ 65	N$ 65
ADS1015	1	N$ 80	N$ 80
Potentiometer	1	N$ 10	N$ 10
GSM SIM900D	1	N$ 1200	N$ 1200
Conductors	-	N$ 300	N$ 300
Diodes	10	N$ 2	N$ 20
Resistors	20	N$ 10	N$ 200
Capacitors	20	N$ 2	N$ 40
Breadboard	8	N$ 90	N$ 720
Amplifiers	2	N$ 6	N$ 12
Zener diodes	6	N$ 10	N$ 60
230V/12V transformer	1	N$ 460	N$ 460
L78S05CV	1	N$ 15.31	N$ 15.31
40A 220V Automatic reconnect over voltage and under voltage protective device	1	N$ 153.10	N$ 153.10
3A CB	1	N$ 107.17	N$ 107.17
			N$ 7685.48

As a result, the estimated bill of quantities shows that the physical monitoring system costs around N$ 7682.48.

CHAPTER 4: RESULTS & DISCUSSIONS

4.1. Physical system

4.1.1. LCD display

The system is shown in the following image, with figure 24 showing the system initial display when it is turned on.

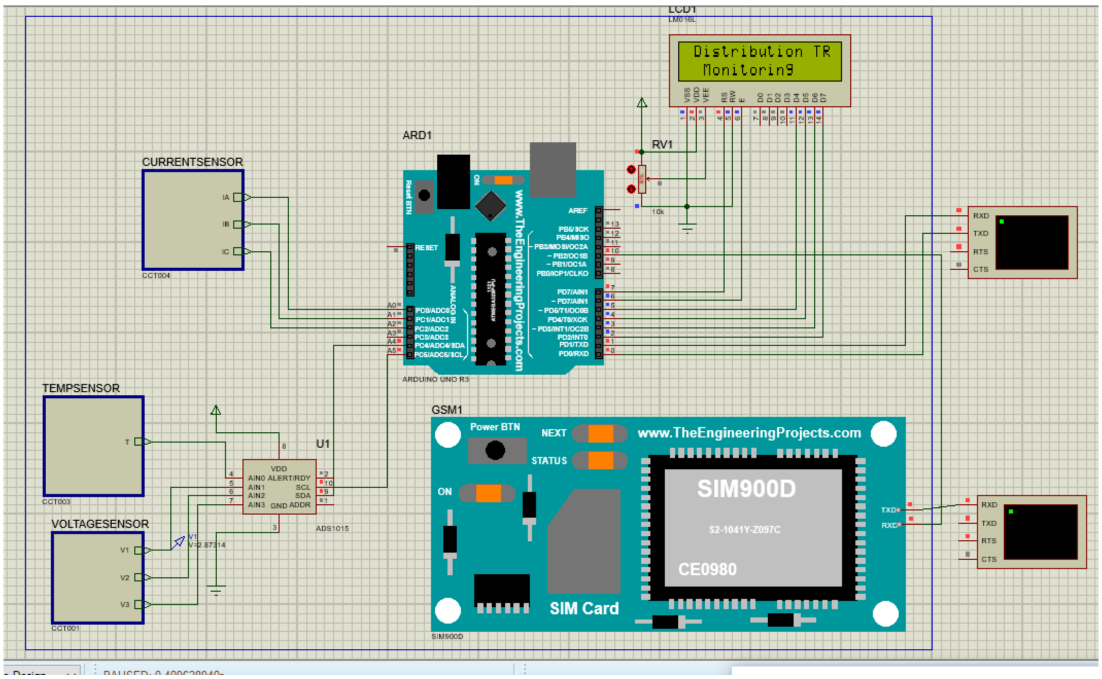

Figure 24: LCD result1.

4.1.1.1. Normal operation conditions

Under normal working conditions, Figures 25,26, and 27 show the system displaying the current readings of phases A, B and C, respectively.

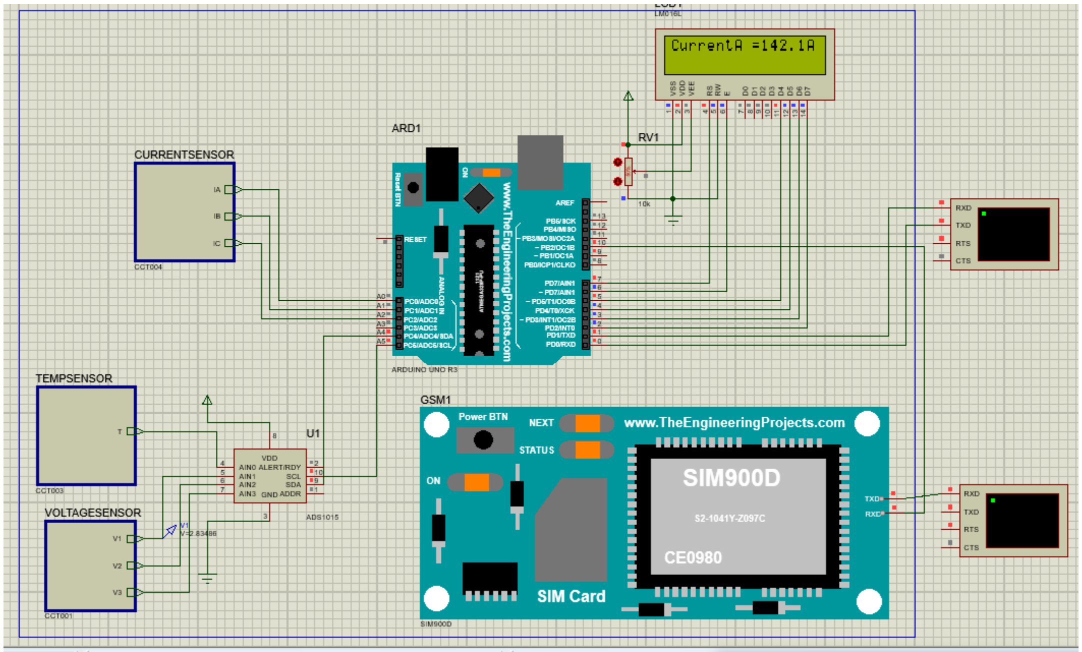

Figure 25: LCD result2.

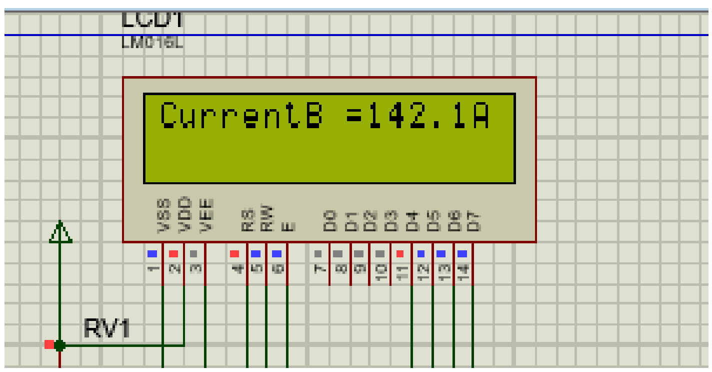

Figure 26: LCD result3.

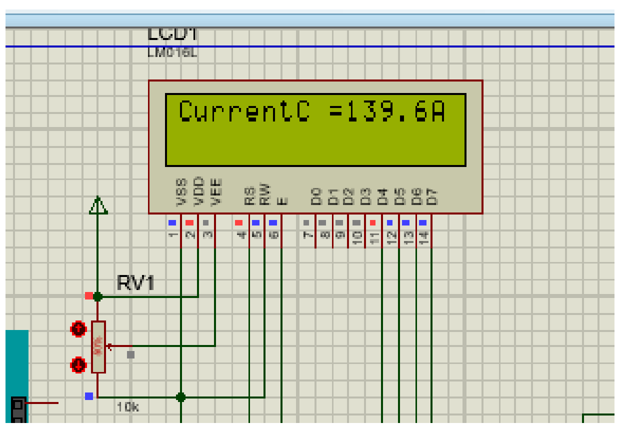

Figure 27: LCD result4

Figure 28 shows the system LCD, which shows that the transformer temperature is within standard limits.

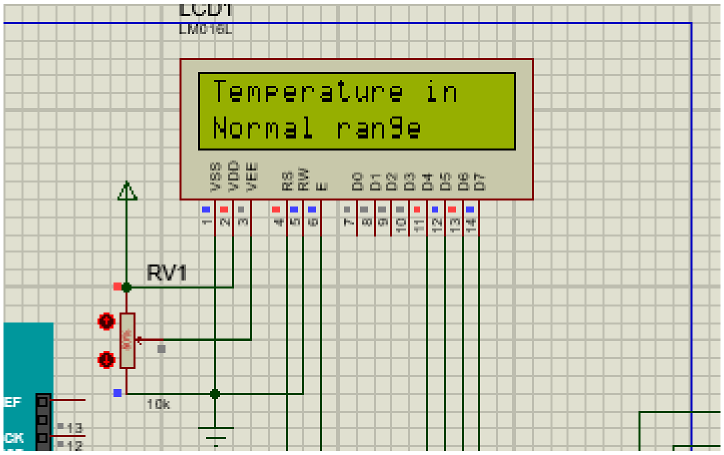

Figure 28: LCD results5.

Under normal working conditions, Figures 29, 30, and 31 show the system displaying the voltage readings of phases an, bn and cn, respectively.

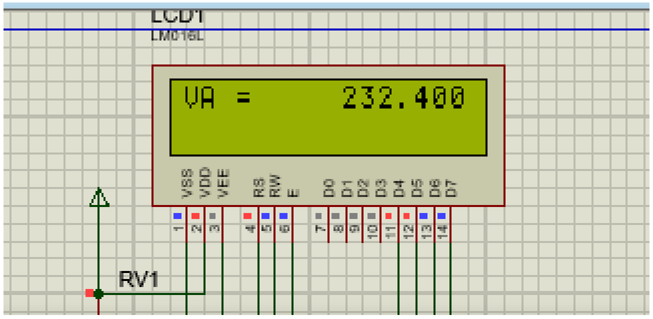

Figure 29: LCD results6.

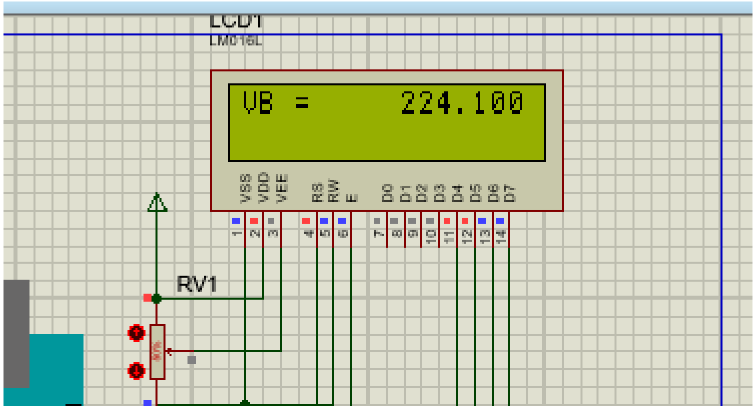

Figure 30: : LCD results7

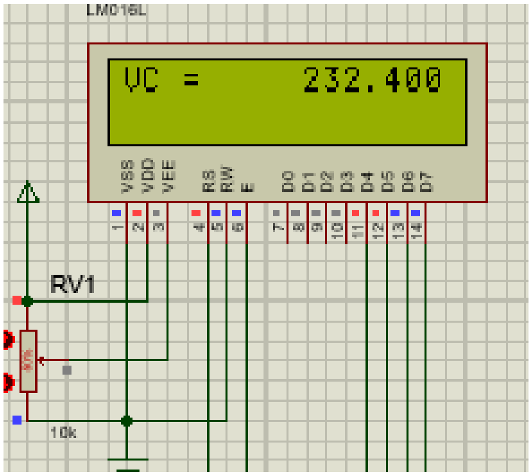

Figure 31: LCD results8.

4.1.1.2. Abnormal operation conditions

Under abnormal working conditions, Figures 32, 33, and 34 show the system displaying the current readings of phases A, B and C, respectively and indicating that current is abnormal.

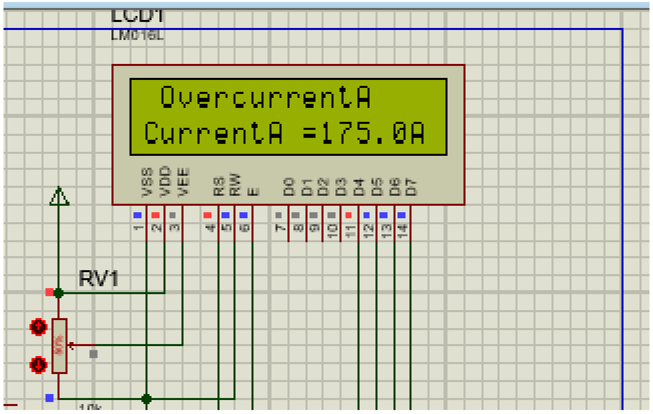

Figure 32: LCD results9.

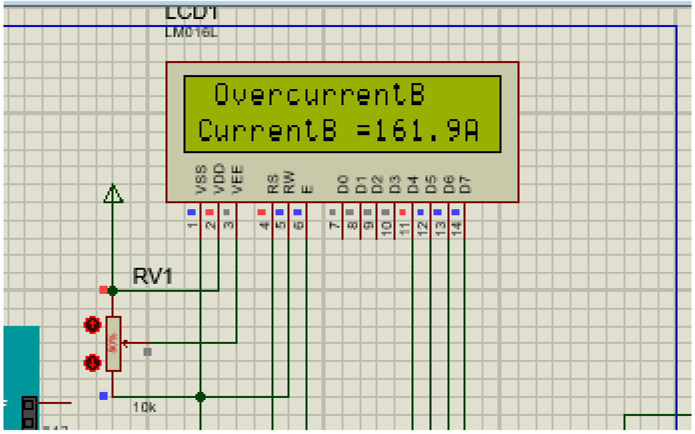

Figure 33: LCD results10.

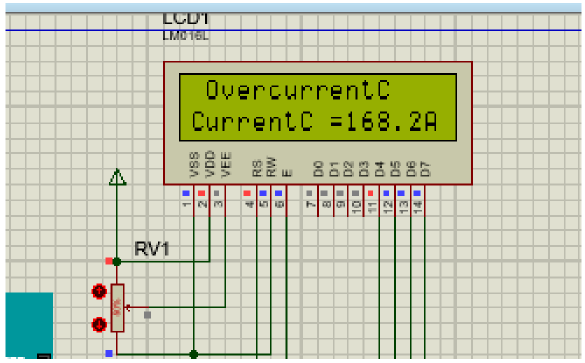

Figure 34: : LCD results11.

The system LCD in Figure 35 shows that the transformer temperature has risen above the normal operating temperature.

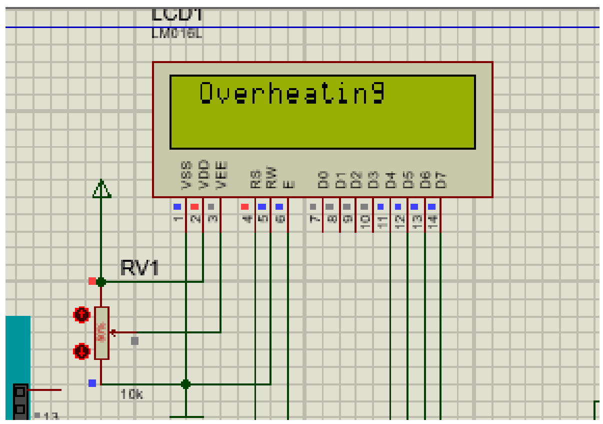

Figure 35: LCD results12.

Under abnormal working conditions, Figures 36, 37, and 38 show the system displaying the voltage readings of phases an, bn and cn, respectively and indicating that voltage is abnormal.

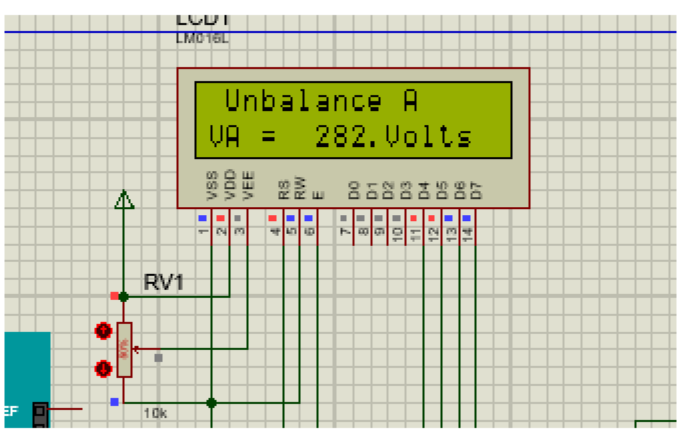

Figure 36: LCD results13.

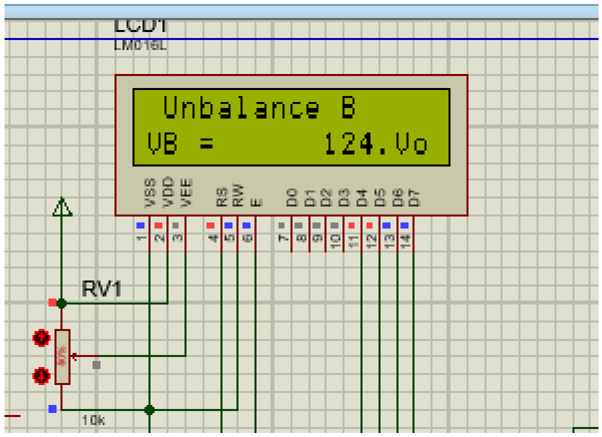

Figure 37: : LCD results14

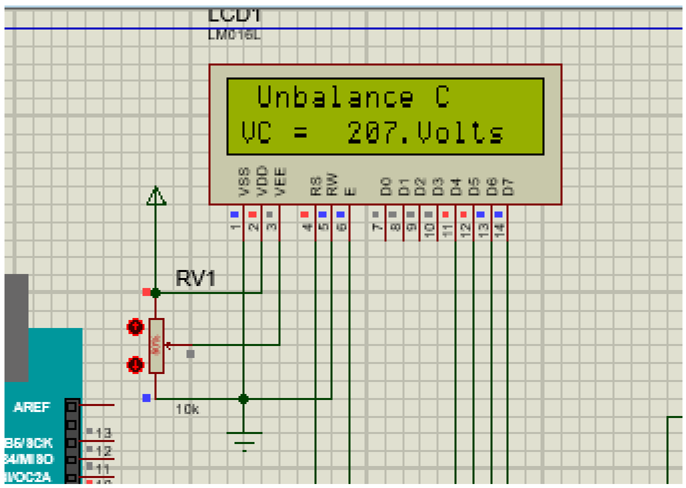

Figure 38: LCD results15.

4.1.2. GSM Results

4.1.2.1. Normal operation conditions

The system is not communicating with the operator, as shown in Figures 39 and 40, because its measured parameters are within acceptable ranges. The virtual terminal in the simulation does not indicate that a message has been sent.

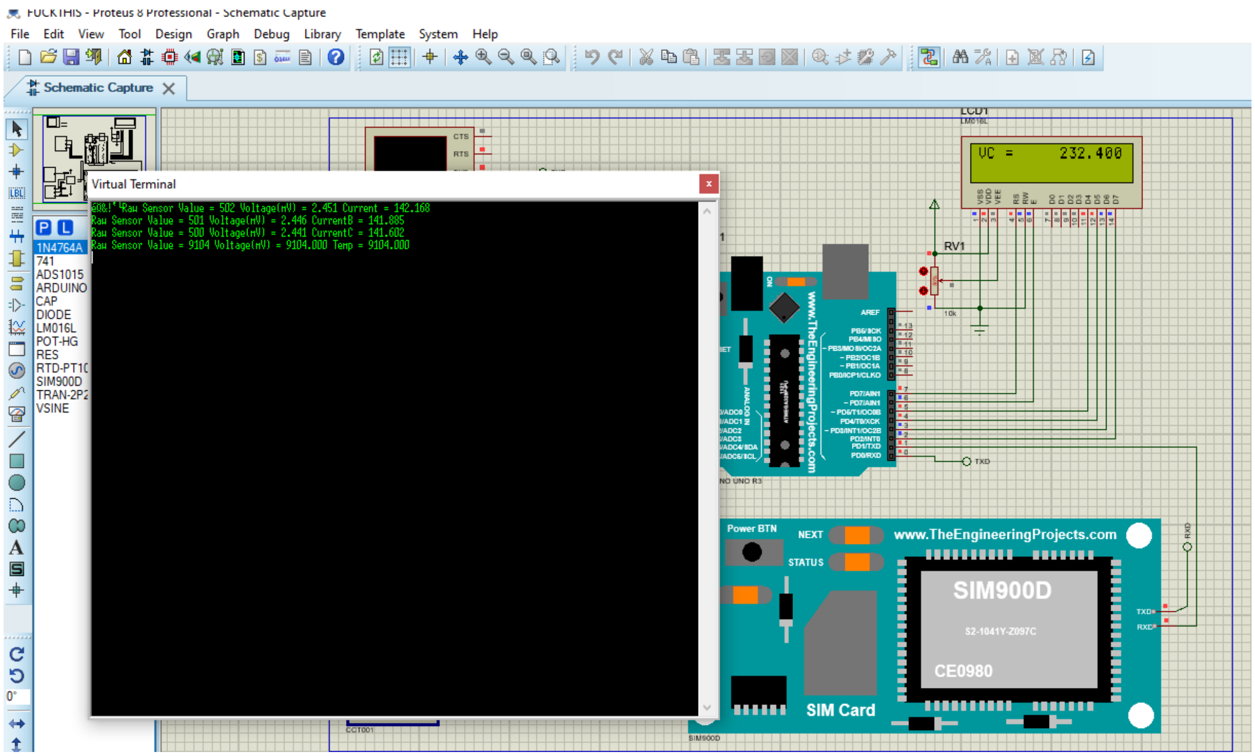

Figure 39: GSM result normal operating conditions1.

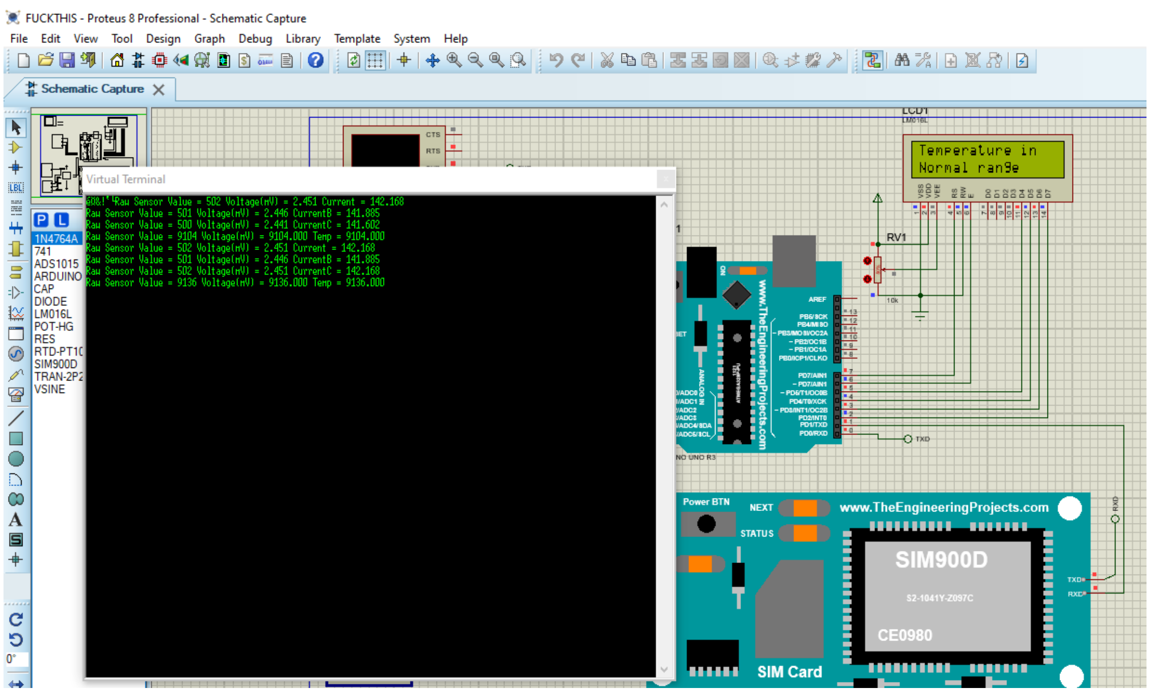

Figure 40: GSM result normal operating conditions2.

4.1.2.2. Abnormal operation conditions

The system is communicating with the operator in Figures 41 and 42 because its measured parameters are outside of acceptable ranges. A message has been sent, as indicated by the virtual terminal in the simulation.

Figure 41: GSM result abnormal operating conditions1

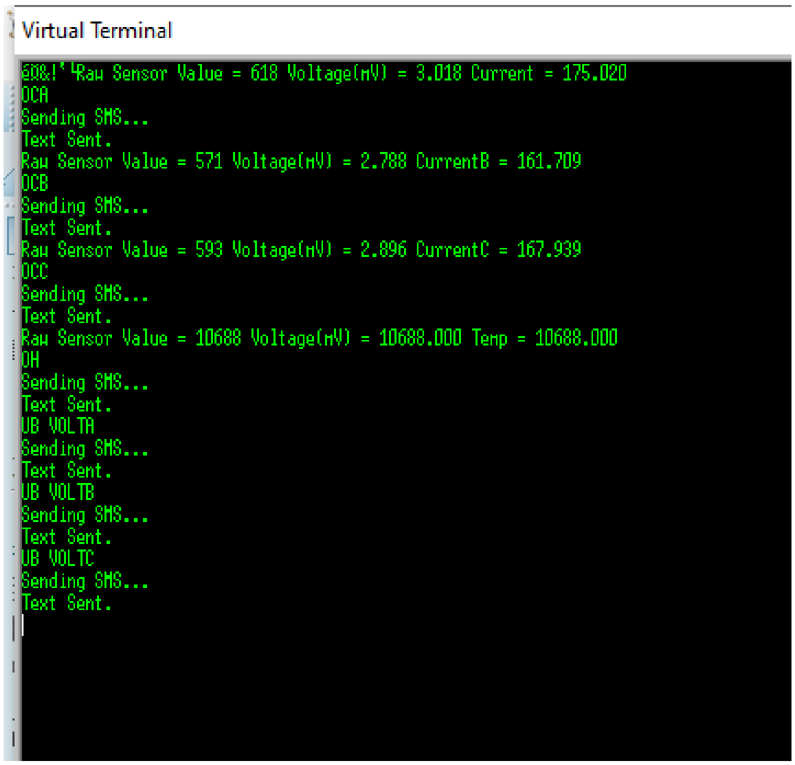

Figure 42: GSM result abnormal operating conditions2

4.2. Monitoring system Prototype

4.2.1. Monitoring system Prototype Components

The following components were used in order to design the system prototype:

- The Arduino Uno was employed as the system's control unit. It processes all of the system's inputs and outputs, as well as making all of the system's decisions.
- As a representation of current and temperature sensors, two 10kohm potentiometers were employed. This was done so that the output could be varied and the system's response could be observed.

- ❖ The GSM SIM 5803 was utilized as the system's and operator's communication channel. It was used to alert the operator if any irregularities in the measured parameters were discovered.
- ❖ The measured parameters were displayed on an I2C LCD display.
- ❖ Using a voltage divider circuit, three 30Kohm and three 7.5Kohm resistors were employed as voltage sensors.

The prototype of the monitoring system and its schematic representation are shown in figures 43 and 44.

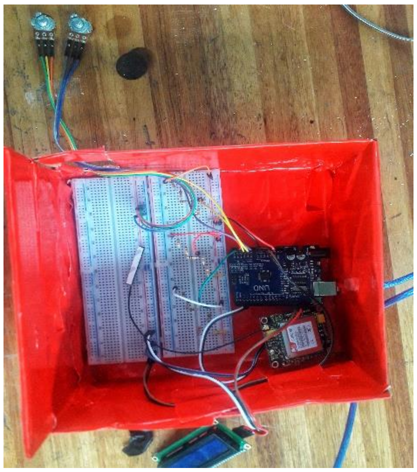

Figure 43: Monitoring system Prototype.

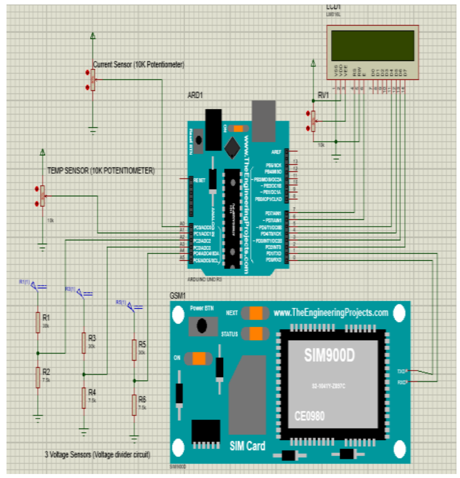

Figure 44: Monitoring system Prototype Schematic Diagram.

4.2.2. Monitoring system Prototype results

Figure 45: Monitoring system Prototype Display.

Figure 45 display the LCD display of the monitoring system prototype measured parameters under normal and abnormal operating conditions. Normal operation conditions where set as current < 24A, temp < 65 degrees, Voltage +-10% of 5V

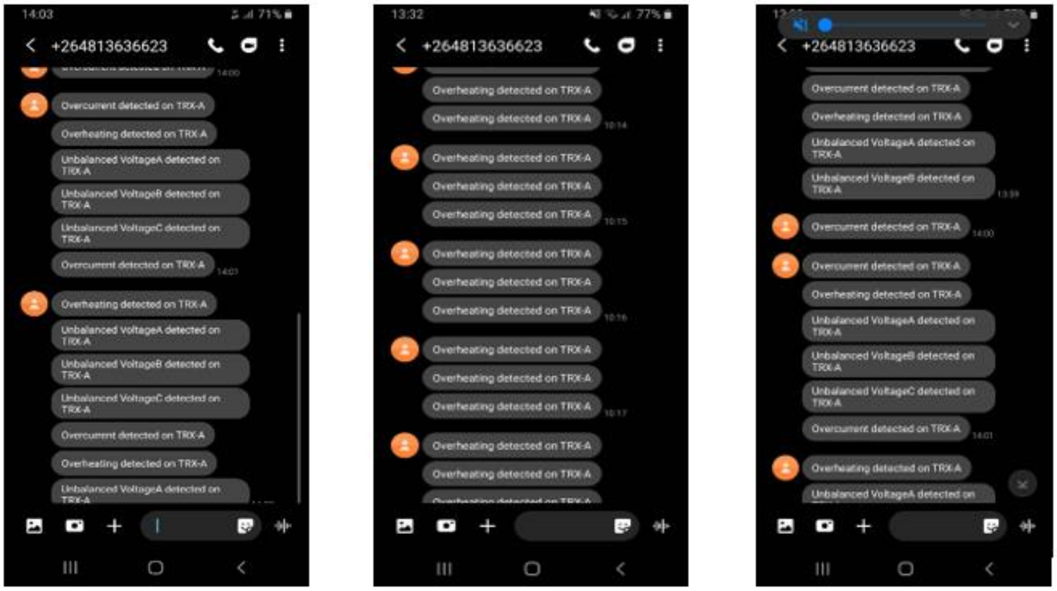

Figure 46: Monitoring system Prototype GSM Communication.

Figure 46 depicts the messages sent to the operator by the monitoring system prototype.

CHAPTER 5: CONCLUSION & FUTURE WORK

5.1. Conclusion

In conclusion, the designed System was able to measure current, voltage and temperature, determine if these parameters were in the normal range and if not send a SMS notification using GSM.

5.2. Future work

1. Back-up power supply.
2. Addition more sensors which will measure the following:

- Oil level & properties
- Earth leakage current

3. A system that can send the measured parameters at the request of the operator.
4. Notification system for the system power supply failure.

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APPENDIX

Appendix A: Transformer Nameplate

Transformer	
Parameter	Quantity
Output KVA	100
Rated Volts HV	33000
Rated Volts LV	400
Rated Current HV	1.75
Rated Current LV	144
Phases	3
Type of cooling	O.N.A.N
Frequency Hz	50
Impedance Volts	4.49%
Vector Group	Dyn 11
Impulse Level kV	200
Core & Winding kg	360
Total Mass kg	835
Oil Quantity Litres	275
DRG.No	5420-3 0352 REV1
Serial No.	10773601/01

Switch Pos. No	1	2	3	4	5
Primary Voltas %	105	102.5	100	97.2	95

Appendix B: Program source code

```
/*

Design of the Distribution Transformers' Monitoring system using GSM codes

Supervisor: Dr. Dickson K. Chembe

Co- Supervisor: Dr. T. Wanjekeche

By

Jürgen Tjiratjiza Viakondo

201613187

 */
#include <LiquidCrystal.h>
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);
#include "ADS1X15.h"
ADS1115 ADS(0x48);
#include <SoftwareSerial.h>
SoftwareSerial sim800l(0, 1); // RX,TX for Arduino and for the module it's TXD RXD, they should be inverted
//PIN A0
const int currentPin = A0;
int adcValue= 0;
double adcVoltage = 0;
double currentValue = 0;
//PIN A1
```

```
const int currentPin2 = A1;
int adcValueB= 0;
double adcVoltageB = 0;
double currentValue2 = 0;
//PIN A2
const int currentPin3 = A2;
int adcValueC= 0;
double adcVoltageC = 0;
double currentValue3 = 0;
//TEMP
double adcVoltageT = 0;
double tempValue = 0;
//VA
float vOUTA = 0.0;
float vINA = 0.0;
//VB
float vOUTB = 0.0;
float vINB = 0.0;
//VC
float vOUTC = 0.0;
float vINC = 0.0;


void setup()
{
  Serial.begin(115200);
  Serial.println(__FILE__);
  Serial.print("ADS1X15_LIB_VERSION: ");
```

```
  Serial.println(ADS1X15_LIB_VERSION);
  ADS.begin();
  sim800l.begin(9600);   //Module baude rate, this is on max, it depends on the version
  delay(1000);
  Serial.begin(9600);
   lcd.begin(16, 2);
   lcd.print(" Distribution TRX ");
   lcd.setCursor(0,1);
   lcd.print("  Monitoring  ");
   delay(2000);
}

void loop()
{
  // Current phase an
  adcValue = analogRead(currentPin);
  adcVoltage = (adcValue * 5.0) / 1024.0;
  currentValue = adcVoltage * 58 ;

  Serial.print("Raw Sensor Value = " );
  Serial.print(adcValue);

  lcd.clear();
  delay(1);
  //lcd.display();

  delay(2);
```

```
Serial.print("\t Voltage(mV) = ");
Serial.print(adcVoltage,3);

delay(2);

Serial.print("\t Current = ");
Serial.println(currentValue,3);

lcd.setCursor(0,0);
if (currentValue <= 150)
{
  lcd.print("CurrentA =       ");
  lcd.setCursor(10,0);
  lcd.print(currentValue,3);
  lcd.setCursor(15,0);
  lcd.print("A");
  delay(2500);
  }
else {
lcd.begin(16, 2);
lcd.print(" OvercurrentA ");
lcd.setCursor(0,1);
lcd.print("CurrentA =");
lcd.setCursor(10,1);
lcd.print(currentValue,2);
lcd.setCursor(15,1);
lcd.print("A");
delay(2500);
```

```
 //GSM
Serial.println("OCA");   //Shows this message on the serial monitor
delay(200);                       //Small delay to avoid detecting the button press many times
Serial.println("Sending SMS...");              //Show this message on serial monitor
sim800l.print("AT+CMGF=1\r");                   //Set the module to SMS mode
delay(100);
sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to include your country code, example +212123456789"
delay(500);
sim800l.print("Overcurrent an at TRX-XX");       //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
delay(500);
sim800l.print((char)26);// (required according to the datasheet)
delay(500);
sim800l.println();
Serial.println("Text Sent.");
delay(500);
if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
  Serial.write(sim800l.read());
}
}
  // Current phase bn
adcValueB = analogRead(currentPin2);
adcVoltageB = (adcValueB * 5.0) / 1024.0;
currentValue2 = adcVoltageB * 58 ;

Serial.print("Raw Sensor Value = " );
Serial.print(adcValueB);
```

```
lcd.clear();
delay(1);
delay(2);
Serial.print("\t Voltage(mV) = ");
Serial.print(adcVoltageB,3);

delay(2);

Serial.print("\t CurrentB = ");
Serial.println(currentValue2,3);

lcd.setCursor(0,0);
if (currentValue2 <= 150)
{
  lcd.print("CurrentB =       ");
  lcd.setCursor(10,0);
  lcd.print(currentValue2,3);
  lcd.setCursor(15,0);
  lcd.print("A");
  delay(2500);
  }
else {
lcd.begin(16, 2);
lcd.print(" OvercurrentB ");
lcd.setCursor(0,1);
lcd.print("CurrentB =");
lcd.setCursor(10,1);
```

```
 lcd.print(currentValue2,2);
 lcd.setCursor(15,1);
 lcd.print("A");
 delay(2500);
 lcd.clear();
 //GSM
 Serial.println("OCB");   //Shows this message on the serial monitor
 delay(200);                         //Small delay to avoid detecting the button press many times
 Serial.println("Sending SMS...");              //Show this message on serial monitor
 sim800l.print("AT+CMGF=1\r");                   //Set the module to SMS mode
 delay(100);
 sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to include your country code, example +212123456789"
 delay(500);
 sim800l.print("Overcurrent bn at TRX-XX");       //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
 delay(500);
 sim800l.print((char)26);// (required according to the datasheet)
 delay(500);
 sim800l.println();
 Serial.println("Text Sent.");
 delay(500);
 if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
   Serial.write(sim800l.read());
 }
 }
   // Current phase cn
adcValueC = analogRead(currentPin3);
```

```
adcVoltageC = (adcValueC * 5.0) / 1024.0;
currentValue3 = adcVoltageC * 58 ;

 Serial.print("Raw Sensor Value = " );
 Serial.print(adcValueC);

 lcd.clear();
 delay(1);

 delay(2);

 Serial.print("\t Voltage(mV) = ");
 Serial.print(adcVoltageC,3);

 delay(2);

 Serial.print("\t CurrentC = ");
 Serial.println(currentValue3,3);

 lcd.setCursor(0,0);
 if (currentValue3 <= 150)
 {
   lcd.print("CurrentC =        ");
   lcd.setCursor(10,0);
   lcd.print(currentValue3,3);
   lcd.setCursor(15,0);
   lcd.print("A");
   delay(2500);
```

```
  }
 else {
  lcd.begin(16, 2);
  lcd.print(" OvercurrentC ");
  lcd.setCursor(0,1);
  lcd.print("CurrentC =");
  lcd.setCursor(10,1);
  lcd.print(currentValue3,2);
  lcd.setCursor(15,1);
  lcd.print("A");
  delay(2500);
  lcd.clear();
//GSM
 Serial.println("OCC");   //Shows this message on the serial monitor
 delay(200);                        //Small delay to avoid detecting the button press many times
 Serial.println("Sending SMS...");              //Show this message on serial monitor
 sim800l.print("AT+CMGF=1\r");                   //Set the module to SMS mode
 delay(100);
 sim800l.print("AT+CMGS=\"+264813941459\"\r");     //Your phone number don't forget to include your country code, example +212123456789"
 delay(500);
 sim800l.print("Overcurrent cn at TRX-XX");       //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
 delay(500);
 sim800l.print((char)26);// (required according to the datasheet)
 delay(500);
 sim800l.println();
 Serial.println("Text Sent.");
 delay(500);
```

```
  if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
    Serial.write(sim800l.read());
  }
  }
    // Temperature
  int16_t val_0 = ADS.readADC(0);
  adcVoltageT = (val_0);
  tempValue = adcVoltageT;

  Serial.print("Raw Sensor Value = " );
  Serial.print(val_0);

  lcd.clear();
  delay(1);
  delay(2);

  Serial.print("\t Voltage(mV) = ");
  Serial.print(adcVoltageT,3);

  delay(2);

  Serial.print("\t Temp = ");
  Serial.println(tempValue,3);
  if (tempValue <= 9968) {
    lcd.begin(16, 2);
    lcd.print("Temperature in");
    lcd.setCursor(0,1);
    lcd.print("Normal range");
```

```
   delay(2500);
   lcd.clear();
   }
  else {
   lcd.begin(16, 2);
   lcd.print(" Overheating ");
   delay(2500);
   lcd.clear();
 //GSM
  Serial.println("OH");   //Shows this message on the serial monitor
  delay(200);                        //Small delay to avoid detecting the button press many times
  Serial.println("Sending SMS...");              //Show this message on serial monitor
  sim800l.print("AT+CMGF=1\r");                  //Set the module to SMS mode
  delay(100);
  sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to include your country code, example +212123456789"
  delay(500);
  sim800l.print("Overheating at TRX-XX");        //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
  delay(500);
  sim800l.print((char)26);// (required according to the datasheet)
  delay(500);
  sim800l.println();
  Serial.println("Text Sent.");
  delay(500);
  if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
   Serial.write(sim800l.read());
  }
```

```
  }
 // Voltage phase an
 int16_t val_1 = ADS.readADC(1);
 vOUTA = (val_1) / 531;
 vINA = vOUTA *8.3;
 lcd.setCursor(0,0);
  if (abs(vINA-230)/230 >= 0.05)
  {
     lcd.begin(16, 2);
     lcd.print(" Unbalance A ");
     lcd.setCursor(0,1);
     lcd.print("VA =");
     lcd.setCursor(6,1);
     lcd.print(vINA,2);
     lcd.setCursor(10,1);
     lcd.print("Volts");
     delay(2500);
     lcd.clear();

//GSM
 Serial.println("UB VOLTA");   //Shows this message on the serial monitor
 delay(200);                        //Small delay to avoid detecting the button press many times
 Serial.println("Sending SMS...");              //Show this message on serial monitor
 sim800l.print("AT+CMGF=1\r");                  //Set the module to SMS mode
 delay(100);
 sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to
include your country code, example +212123456789"
 delay(500);
```

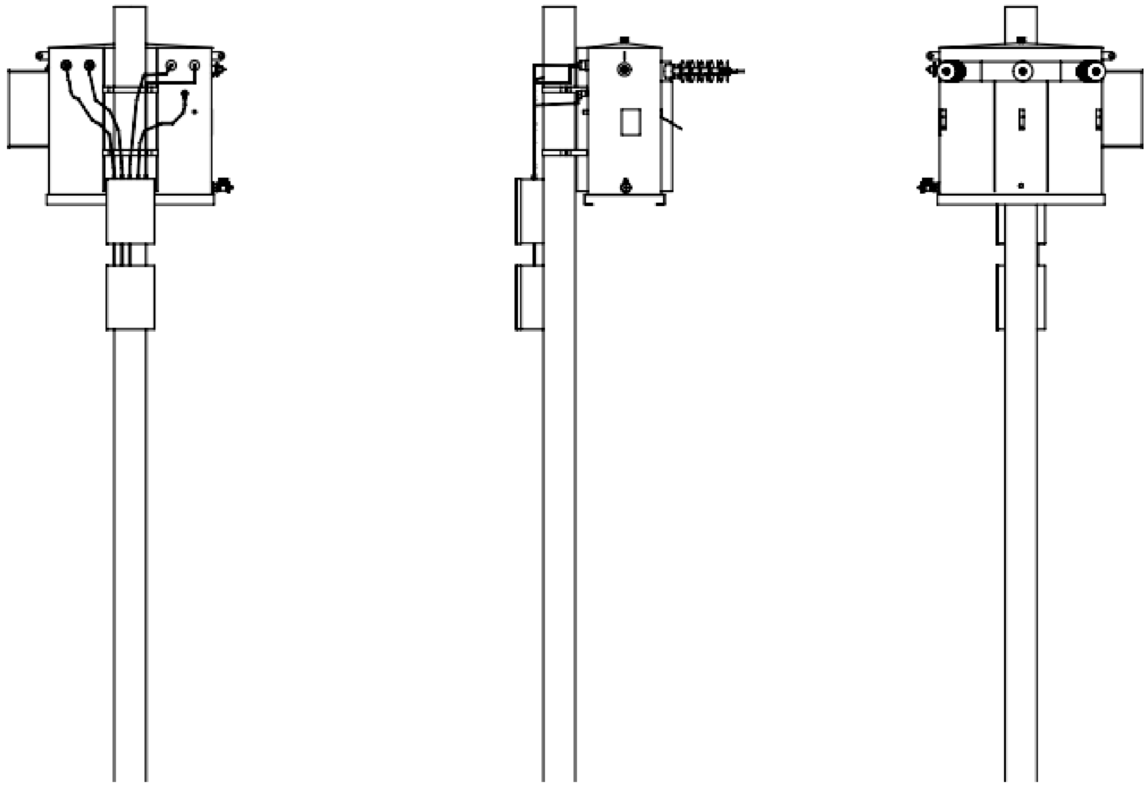
```
  sim800l.print("Unbalance voltage an at TRX-XX");        //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
  delay(500);
  sim800l.print((char)26);// (required according to the datasheet)
  delay(500);
  sim800l.println();
  Serial.println("Text Sent.");
  delay(500);
  if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
    Serial.write(sim800l.read());
  }
      }
    else {
      lcd.print("VA =         ");
      lcd.setCursor(9,0);
      lcd.print(vINA,3);
      lcd.print("Volts");
      delay(2500);
    }
    // Voltage phase bn
  int16_t val_2 = ADS.readADC(2);
  vOUTB = (val_2 ) / 531;
  vINB = vOUTB * 8.3;
  lcd.setCursor(0,0);
  if (abs(vINB-230)/230 >= 0.05)
   {
      lcd.begin(16, 2);
      lcd.print(" Unbalance B ");
```

```
    lcd.setCursor(0,1);
    lcd.print("VB =");
    lcd.setCursor(10,1);
    lcd.print(vINB,2);
    lcd.setCursor(14,1);
    lcd.print("Volts");
    delay(2500);
    lcd.clear();

//GSM
  Serial.println("UB VOLTB");   //Shows this message on the serial monitor
  delay(200);                       //Small delay to avoid detecting the button press many times
  Serial.println("Sending SMS...");              //Show this message on serial monitor
  sim800l.print("AT+CMGF=1\r");                  //Set the module to SMS mode
  delay(100);
  sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to include your country code, example +212123456789"
  delay(500);
  sim800l.print("Unbalance voltage bn at TRX-XX");        //This is the text to send to the phone number, don't make it too long or you have to modify the SoftwareSerial buffer
  delay(500);
  sim800l.print((char)26);// (required according to the datasheet)
  delay(500);
  sim800l.println();
  Serial.println("Text Sent.");
  delay(500);
  if (sim800l.available()){            //Displays on the serial monitor if there's a communication from the module
    Serial.write(sim800l.read());
```

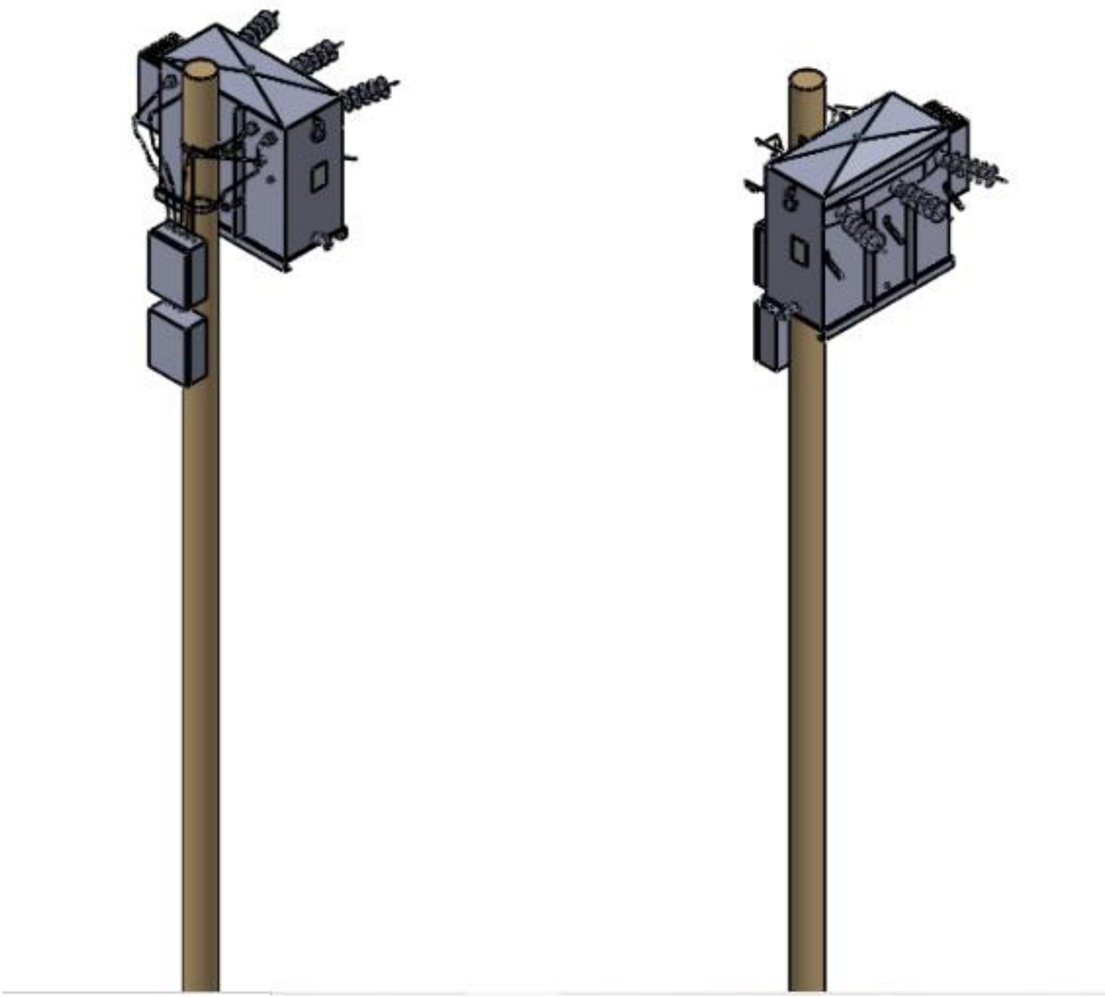
```
}
  }
else {
  lcd.print("VB =         ");
  lcd.setCursor(9,0);
  lcd.print(vINB,3);
  lcd.print("Volts");
  delay(2500);
  }
// Voltage phase cn
int16_t val_3 = ADS.readADC(3);
vOUTC = (val_3 ) / 531;
vINC = vOUTC* 8.3;
lcd.setCursor(0,0);
 if (abs(vINC-230)/230 >= 0.05)
 {
    lcd.begin(16, 2);
    lcd.print(" Unbalance C ");
    lcd.setCursor(0,1);
    lcd.print("VC =");
    lcd.setCursor(6,1);
    lcd.print(vINC,2);
    lcd.setCursor(10,1);
    lcd.print("Volts");
    delay(2500);
    lcd.clear();

//GSM
```

```
  Serial.println("UB VOLTC");   //Shows this message on the serial monitor
  delay(200);                          //Small delay to avoid detecting the button press many times
  Serial.println("Sending SMS...");              //Show this message on serial monitor
  sim800l.print("AT+CMGF=1\r");                   //Set the module to SMS mode
  delay(100);
  sim800l.print("AT+CMGS=\"+264813941459\"\r");    //Your phone number don't forget to
include your country code, example +212123456789"
  delay(500);
  sim800l.print("Unbalance voltage cn at TRX-XX");        //This is the text to send to the phone
number, don't make it too long or you have to modify the SoftwareSerial buffer
  delay(500);
  sim800l.print((char)26);                 // (required according to the datasheet)
  delay(500);
  sim800l.println();
  Serial.println("Text Sent.");
  delay(500);
  if (sim800l.available()){            //Displays on the serial monitor if there's a communication from
the module
    Serial.write(sim800l.read());
  }
    }
  else {
    lcd.print("VC =         ");
    lcd.setCursor(9,0);
    lcd.print(vINC,3);
    lcd.print("Volts");
    delay(2500);
    }
}
```

Appendix C-1: Back-Side-Front View of the monitoring system connected to the transformer.



Appendix C-2: 3D image of the monitoring system connected to the transformer.



Appendix C-3: Monitoring system connections.