Condition based health monitoring of Transformers

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Electrical and Electronics Engineering

by

ADITI SARKAR

15BEE0132

Under the guidance of

Prof. Gokulakrishnan G

School of Electrical Engineering

VIT, Vellore

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<u>DECLARATION</u>

I hereby declare that the thesis entitled **“Condition based health monitoring of transformers”** submitted by me, for the award of the degree of *Bachelor of Technology in Electrical and Electronics Engineering* to VIT is a record of bonafide work carried out by me under the supervision of **Prof. Gokulakrishnan G**.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place : Vellore

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Signature of the Candidate

CERTIFICATE

This is to certify that the thesis entitled **“Condition based health monitoring of transformers”** submitted by **Aditi Sarkar 15BEE0132**, School of Electrical and Electronics Engineering, VIT University, for the award of the degree of *Bachelor of Technology in Electrical and Electronics Engineering* is a record of bonafide work carried out by him under my supervision during the period, 01. 12. 2018 to 30.04.2019, as per the VIT code of academic and research ethics.

The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The thesis fulfills the requirements and regulations of the University and in my opinion meets the necessary standards for submission.

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Date :

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Internal Examiner **External Examiner**

Head of the Department

School of Electronics Engineering

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Executive Summary

Transformers are essential component of electrical distribution as well as transmission system. There are many faults which can take place in transformers because of the over-voltage and excessive heating. If we can get the information about these factors, then the problem can be taken care of in the meantime. Thus, the health monitoring of the transformers is very important. Condition based health monitoring of the transformers will be able to prevent the overhaul interruption in the distribution and transmission system. Along with it, it is also important to check the dielectric strength of the oil used in the transformers because its dielectric strength will decrease after a certain interval of time and then the oil inside the transformer should be replaced with the fresh oil.

In this project we have collected the data of the transformers of Vit Vellore as well as Tamil Nadu Electricity Board (TNEB) Gandhinagar and collected two oil samples from Silver Jubilee Tower (SJT) and Tamil Nadu Electricity Board (TNEB) to perform the test of dielectric strength. Simulation for the monitoring of transformers is done using Proteus Professional 8 software where the parameters like temperature and voltage are monitored. The hardware model is made for the monitoring of the voltage, power, temperature and oil level so that it can be used to prevent the fault in the transformer.

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List of Abbreviations

TNEB	Tamil Nadu Electricity Board
S.J.T	Silver Jubilee Tower
IDE	Integrated Development Environment
MHz	Megahertz
KΩ	Kilo-ohm
ICSP	In-Circuit System Programming
EEPROM	Electrically Erasable Programmable Read Only Memory
ICs	Integrated Circuits
STD	Standard Tessellation Language
E.M.F	Electromotive force
LCD	Liquid Crystal Display
BDV	Breakdown Voltage
Temp.	Temperature

Symbols and Notations

L	Distance
T	Time
C	Sonic Speed
Ω	Ohm
δ	Step-Value

1. INTRODUCTION

1.1. OBJECTIVE

This project is mainly made to gather information from distribution transformers in order to monitor and control the entire electric distribution grid efficiently and reliably. It will act as a decision support system to assist the grid operation engineers with information that helps to estimate the load, fix problems and identify the week points in the grid.

The main objective of this project is to build a system to acquire the remote electrical signals from distribution transformers such as voltage, power, oil level and temperature, along with exact date and time of measuring. At the monitoring node, after receiving the information, it can be saved into databases and also display the data on a screen for use by the operation engineers. We propose a system that detect faults in remote transformers lines, and immediately transmit any fault information to multiple people like line man, power house, Electricity board office etc.

Since the project involves power systems, sensors and signal processing and microcontroller, a lot of study needs to go into understanding how to model, simulate and connect these three different fields. An effort to reach a higher level of understanding especially of PROTEUS Professional 8 is also considered an objective of the project otherwise this project wouldn't have even worked out.

1.2. MOTIVATION

These days power companies invest a lot of money into augmentation of their power systems especially transmission and generation. Power transformers, although terribly less in range, play a crucial role within the transmission of power in an electrical grid. They are an important node that carry large amount of electricity in the process of transmission and distribution. Throughout its operation, power transformers are subjected to varied stresses as well as thermal and electrical. If not monitored, these abnormalities can deteriorate the transformer windings and turn out early faults that go unnoted. Transformer failures may cause power outages, personal and environmental hazards and costly rerouting or purchase of power from alternative suppliers. Transformer failures will occur because of varied causes. In-service interruptions in transformers and failures sometimes result from breakdown in materials, distortion in winding caused by short-circuit stand up to, electrical disturbances, deterioration of insulation, lightning, inadequate maintenance, loose connections, overloading etc. Desegregating the 'individual cause' observance permits for observance of the overall condition of transformer. The mandatory steps involved are observation of the voltage, power, temperature and transformer oil. The transformer oil (insulation oil) of voltage- and current-transformers fulfills the aim of insulating still as cooling. Thus, the dielectric quality of transformer oil is crucial for safe and secure operation of a transformer. The transformer oil degrades through aging and moisture ingress, transformer oil ought to, depending on economics, transformer duty and other factors, be tested periodically.

The main motivation of this project is to produce a buzzing sound whenever we detect any sudden rise or fall in temp., voltage or power of the transformer and then alerting people like line man, power house, Electricity board office etc. to take the necessary steps. With the help of these testing, transformers' life can be substantially increased, which will delay new investments on replacement transformer assets.

1.3. BACKGROUND

With the invention of the primary constant-potential transformer in the year 1885, transformers became essential for the transmission, distribution, and utilization of AC electric power. Observation and on-the-scene nosology of electrical instrumentality, specially transformers, has attracted considerable attention for many years. This interest has accelerated over the last years triggered by structural changes within the electricity business. There's type of trends and developments during this space once seen from a manufacturer's perspective. Transformers, that either raise a voltage to decrease losses, or decrease voltage to a secure level, are thought-about among the foremost dearly-won instruments of the transmission and distribution system. Transformers are expensive, as is that the value of power interruptions. The savings that will be obtained from the bar of failures in transformers would be within the ample bucks.

Earlier, maintenance of enormous high voltage transformers was supported by a pre-determined schedule. Maintenance crews would examine the transformer at set intervals on the idea, of its age and performance history. As is expected, this winds up in many harmful failures of improperly diagnosed transformers and therefore the over review of different transformers. All the price of scheduled and unscheduled maintenance, particularly at remote sites, due to this the utility trade has begun finance in instrumentation and observation of transformers. Maintaining information of nosology of the electrical device at each instant is that the key to greatly scale back the price and increase the reliableness of providing the required power to a growing society.

1.4. LITERATURE REVIEW

Power transformers, play a vital role within the transmission of power in an electrical grid. They're the important node that carry vast volume of electricity. Throughout its operation, power transformers are subjected to numerous stresses together with thermal and electrical. If not monitored, these abnormalities can deteriorate the transformer windings and turn out inchoate faults that go unmarked. A transformer has a set of copper windings that's primary and secondary and a core. Primary and secondary windings are always isolated from one another and also the core of the transformer. The employment of principle of mutual induction transfer the ability from one aspect to different. Throughout the operation multiple forces like enlargement and contraction takes place through the full the thermal cycles, vibrations within the core thanks to presence of the continual electrical flux, heating within the core caused by the eddy currents, and thermal heating that's typically caused by overloading. Preventive monitoring of transformers for the faults before they are available out will forestall their prevalence, that are very costly to repair and cause the deprivation of power offered. Condition based health observation is that technique throughout which operational characteristics of transformers are observed and changes discovered in those operational characteristics are used for prognostic maintenance.

In this project we propose to form a system that uses the remote electrical signals from the distribution transformers like voltage, power, oil level and temperature, along with exact date and also the time of measurement. At the node of monitoring, after receiving the information, it can be saved into databases and also shows the respective data on a screen for use by the operation engineers assigned. We propose a system that detect faults in remote transformers lines, and immediately transmit any fault information to some fixed people working in the electricity board department.

2. PROJECT DESCRIPTION AND GOALS

2.1 Project description

2.1.1 Data collection and Oil testing

We collected the ratings and other details about the maintenance of the transformers of VIT, Vellore and Tamil Nadu Electricity Board (TNEB), Gandhinagar. Along with that we collected used oil sample from SJT's Transformer and Tamil Nadu Electricity Board (TNEB), Gandhinagar. On that used oil sample we performed Dielectric Strength Testing in laboratory.

2.1.2 Simulation

We performed the simulation of fault detection in Transformer using various parameters like voltage, temperature and oil level. In the simulation we are monitoring the transformer of rating 2.2kv/220v. ATMEGA328P is used as a microcontroller to perform the operation. On the secondary side of the transformer, we have used a rectifier circuit in order to convert AC signal into DC signal as we cannot input AC signal to ATMEGA328P microcontroller. We have used the LCD to display the value of output voltage and temperature of the transformer. Temperature is measured by LM35 Temperature Sensor and if the temperature rises after a certain value then a fan is used for the cooling purposes and a buzzer will start. Pins of Temperature sensor and LCD display are connected to the digital pins of the microcontroller so as to ensure to get the digital output. We have also used a RESET button in order to reset the circuit and an oscilloscope is used to get the output waveform from the secondary side of the transformer.

2.1.3 Hardware Modelling

This is the most important part of the project where we convert the whole simulation project into a hardware model and made it more efficient by applying loads of values 40W, 40W and 10W. In the hardware modelling, we have also used Ultrasonic sensor for measuring the oil level of transformer.

2.2 Goals

The goals of this project are as follows:

1. To understand how to measure Dielectric Strength of oil of transformer.
2. To have basic understanding of PROTEUS Professional 8 software.
3. To develop simulation circuit to monitor the health of a transformer.
4. To develop algorithm and code for converting electrical signals generated by Temperature sensor and Ultrasonic sensor into user readable format.
5. To develop algorithm for finding the current and then the respective power using current sensing circuit.
6. To set a particular range for voltage, temp., power and oil level for detecting the faults in a transformer.

3. Technical Specification

3.1 Proteus Professional 8

The PROTEUS is an electronic circuit design software which includes features like simulation, schematic capture and PCB layout modules. It is a free trial software application. The operating system used is windows. The initial release of this software was in 1988 in Yorkshire, England by LABCENTER ELECTRONICS Ltd. We can simulate our work and be more efficient in completing the task at hand. We used this software in designing and simulating circuit for condition-based health monitoring of transformers. Here we are able to vary the parameters of a transformer like voltage, current, oil level of transformer and temperature which is automatically getting varied with the variation of one parameter and shows different outputs at different inputs applied.

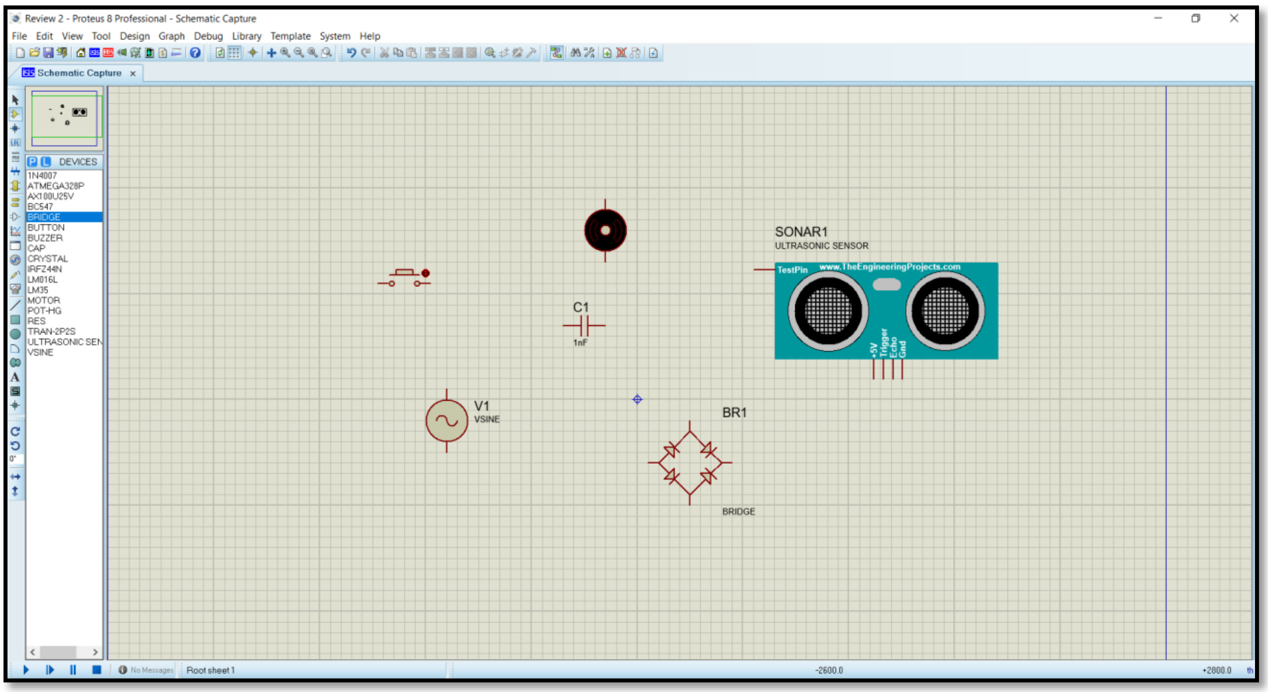

Fig. 3.1 Screenshot of Proteus Workspace

3.2 Arduino UNO

Arduino UNO is a microcontroller- based open source electronic prototyping board which can be programmed with an easy-to-use Arduino IDE. This microcontroller board is based on the ATmega328P. Arduino consists of both a physical programmable circuit board and a piece of software, or IDE. The Arduino IDE uses a simplified version of C++, making it easier to learn. It has 20 digital input/output pins, of which 6 can be used as PWM outputs and 6 can used as analog inputs. It also has 16MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button.

3.3 Current Sensor

A current sensor is used to detect electric current which is flowing in a wire and it then convert that current to easily measure the output voltage, that will be proportional to the flowing current through the measured path. The current which is when passed through the electrical circuit, the voltage will drop across the path through which the current is passing. A magnetic field will also be generated which will be near to the current carrying conductor. This technique is used to design the current sensor.

In our project we are using current sensor in hardware model in varying the current of transformer according to the power consumed by the load applied across it with 2 loads of 40 watts and 1 load of 10 watts.

3.4 Thermocouple

The thermocouple is outlined as a temperature sensing element that's used to measure the temperature at one specific point in the form of the E.M.F or an electric current. This sensing element contains two dissimilar metal wires that are connected together at one junction. The temperature is often measured at this junction, and also the modification in temperature of the metal wire stimulates the voltages.

The amount of EMF generated in the thermocouple is incredibly minute (millivolts), so very sensitive devices must be utilized for calculating the E.M.F produced in the circuit. The common devices used to calculate the E.M.F are voltage balancing potentiometer and the ordinary galvanometer. From these two, a balancing potentiometer is used physically or mechanically.

When two wires composed of different metals are joined at every ends and one of the ends is heated, there is a continual current that flow inside the thermoelectrical circuit. If this circuit is broken at the centre, the net voltage of the open circuit may be a perform of the junction temperature and therefore the composition of the metals. That implies that once the junction of two metals is heated or cooled then a voltage is generated which will be related to the temperature.

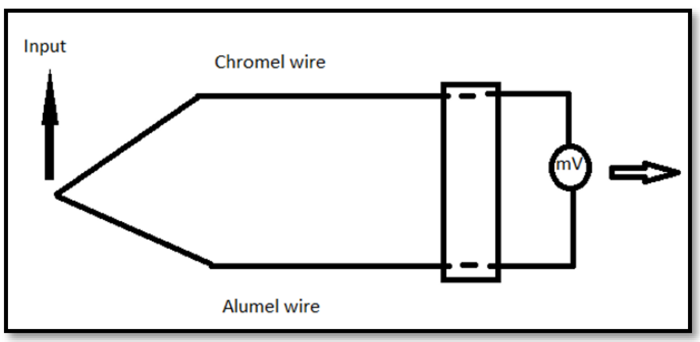

Fig. 3.2 Thermocouple

In our hardware project we have used Surface Probe Thermocouples. In order to ensure a correct measurement, the complete measurement space of the sensing element should be in-tuned with the surface. This can be tough once operating with a rigid sensing element and a solid surface. Since, they're product of pliable metals, the junction will be fashioned flat and thin to produce most contact with a solid surface. These thermocouples ar a wonderful alternative for surface calculation.

3.5 Ultrasonic Sensor

Ultrasonic sensors are used to measure the live distance through inaudible ultrasonic waves. The device head emits associate ultrasonic wave and receives the wave mirrored back from the target. Ultrasonic sensors are used to measure the gap to the target by calculating the time between the emission and reception of signals. Using the following formula, the distance can be calculated:

Distance $L = 1/2 \times T \times C$

where L is the dist., T is the time between the emission and reception, and C is the sonic speed.

(The value is multiplied by 1/2 because T is the time for go-and-return distance.)

One of the everyday characteristics shown by the Ultrasonic detection system is- Detection of clear objects, since Ultrasonic waves will mirror off a glass or liquid surface and come to the device head, even clear or transparent targets is detected. We have used this property of Ultrasonic sensor in our project to detect the oil level of a transformer. Also, the detection will not get affected by accumulation or collection of dust or dirt which makes the Ultrasonic sensor most preferable choice for our project.

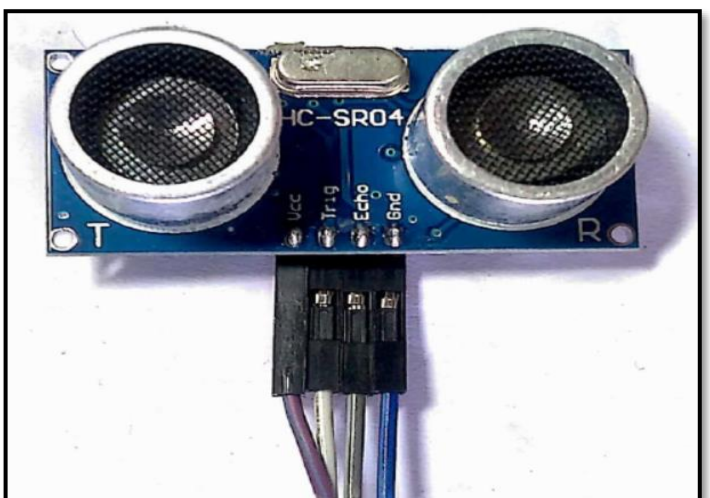

Fig 3.3 Ultrasonic Sensor

3.6 Preset

A preset which is also known as variable resistance is 3 pin electrical device which is used to vary resistance in the circuit. It is changed by rotating the rotary part which is present on the top surface of the preset. Screw driver can be used to rotate that part and thus adjust the value of resistance. Resistance vary in logarithmic or exp. manner. It is a kind of variable resistor which can be used to adjust sensitivity.

Variable resistance is measured across one point at front and the other amongst the two alternative terminals. The two points connected at back supply more resistance that is divided by the front point.

4. DATA COLLECTION AND OIL TESTING

4.1 Data Collection

We have collected the data of the transformers of VIT Vellore and TNEB Gandhinagar.

From VIT Vellore, we have collected the data from the transformers of University Power House and Technology Tower.

4.1.1 University Power House Transformer

Manufacturer – Schneider Electric

Ratings –

Table 4.1 Ratings of University Power House Transformer

KVA	2000
VOLTS AT NO LOAD	11000 (H.V), 433 (L.V)
AMPERES	104.97 (H.V), 2666.7 (L.V)
PHASES	3
TYPE OF COOLING	ONAN
FREQUENCY	50 Hz
IMPEDENCE (VOLTS)	6.78%
CORE AND WINDING (Kg)	1160
WEIGHT OF OIL (Kg)	1300
TOTAL WEIGHT (Kg)	6700
OIL (L)	1495
YEAR OF MANUFACTURE	2017
TEMP.RISE (DEGREE C)	40 (OIL), 45 (WDG)
ENERGY EFFICIENCY LEVEL	1

4.2.2 Technology Tower Power House Transformer

1. T.T Power house Transformer 1 –

   Manufacturer – Crompton Greaves

   Ratings –

Table 4.2 Ratings of T.T Power house Transformer 1

KVA	800)
VOLTS AT NO LOAD	11000 (H.V), 433 (L.V)
AMPERES	42 (H.V), 1066.7 (L.V)
PHASES	3
DIAGRAM DRG.NO.	RDM 5132
MAKER’S SEAL NO.	MT 5132
TYPE OF COOLING	ONAN
FREQUENCY	50 Hz
IMPEDENCE (VOLTS)	4.71%
CORE AND WINDING (Kg)	1160
WEIGHT OF OIL (Kg)	525
TOTAL WEIGHT (Kg)	2600
OIL (L)	600
YEAR OF MANUFACTURE	05/2004

2. T.T Power House Transformer 2 –

Manufacturer – AREVA

Ratings-

Table 4.3. Ratings of T.T Power house Transformer 2

RATED KVA	800
RATED KV	11 (H.V), 0.433 (L.V)
LINE AMPERES	42 (H.V), 1066.7 (L.V)
PHASES	3
DIAGRAM DRG.NO.	D356370
MAKER’S SEAL NO.	T-6370
TYPE OF COOLING	ONAN
FREQUENCY	50 Hz
IMPEDENCE (VOLTS)	4.80%
CORE AND COIL (Kg)	1500
WEIGHT OF OIL (Kg)	530
TOTAL WEIGHT (Kg)	3230
OIL (L)	610
YEAR OF MANUFACTURE	2006

4.2.3 Tamil Nadu Electricity Board (TNEB) Transformer

Manufacturer – Senthil Engineering Company Transformer

Ratings –

Table 4.4 Ratings of TNEB Transformer

KVA	100
VOLTS AT NO LOAD	11000 (H.V), 433 (L.V)
AMPERES	5.25 (H.V), 133.3 (L.V)
PHASES	3
DIAGRAM DRG.NO.	RDM 5132
MAKER’S SEAL NO.	SECO/213
TYPE OF COOLING	ONAN
FREQUENCY	50Hz
IMPEDENCE (VOLTS)	4.5%
CORE AND WINDING (Kg)	245
WEIGHT OF OIL (Kg)	150
TOTAL WEIGHT (Kg)	580
OIL (L)	190
YEAR OF MANUFACTURE	1988
TEMP.RISE (DEGREE C)	55 (OIL), 45(WDG)
ENERGY EFFICIENCY LEVEL	1

4.2 Oil testing

The transformer oil also known as insulating oil is very stable at high temperature and also has the electrical insulating properties which are excellent. The transformers in the transmission and distribution process are used to insulate, stop corona discharge, and also stops the dissipation of heat from the transformer. We are performing this test to check the dielectric strength of the oil because it is also an important parameter in the context of health monitoring. The Breakdown Voltage (BDV) is the other name which is used for the dielectric strength of the oil. The lower the value of the breakdown voltage, the higher the amount of conducting substances and higher the moisture present in the oil.. We have observed the six readings of each oil sample and then took he average of all the readings to get the corresponding dielectric strength. The apparatus used for measuring the dielectric strength is shown in Fig. 4.2.

Fig. 4.1 Transformer oil test set

4.2.1 Oil sample from SJT Power House, VIT Vellore

Table 4.5 Dielectric strength of Oil sample from SJT Power House

OBSERVATION	DILECTRIC STRENGTH OF OIL (KV)
1.	12
2.	10.5
3.	11
4.	11.5
5.	11
6.	11
AVERAGE	11.16

It can be inferred from the above value that the dielectric strength of the oil sample is 11.16 kV. Thus, the voltage supplied to the transformer should not exceed this value as it can cause heavy damage to the oil as well as the transformer and it cannot supply the desired output voltage.

4.2.2 Oil sample from TNEB, Gandhinagar, Vellore

Table 4.6 Dielectric strength of Oil sample from TNEB Gandhinagar

OBSERVATION	DILECTRIC STRENGTH OF OIL (KV)
1.	11.8
2.	11.8
3.	11.7
4.	11.8
5.	11.7
6.	11.8
AVERAGE	11.76

It can be inferred from the above value that the dielectric strength of the oil sample is 11.76 kV. Thus, the voltage supplied to the transformer should not exceed this value as it can cause heavy damage to the oil as well as the transformer and it cannot supply the desired output voltage.

5. DESIGN APPROACH AND DETAILS

5.1 Design Approach

There are three major parts of this project. The first part is the data collection and the testing of dielectric strength of oil samples. The second part is the simulation using Proteus software to monitoring the parameter of the transformer like voltage and temperature. The third part is the most important part as it is the hardware model and it gives the real time values of the parameters like voltage, power, temperature and oil level.

5.2 Simulation for transformer monitoring

To develop the simulation circuit, we have used the main transformer as the source and the step-down transformer to reduce the voltage in order to supply it to the components without damage. The bridge rectifier model we have used here is in order to change the ac to dc voltage as the microcontroller we have used here is ATMEGA325P and it will work only when the DC supply will be applied to it. The circuit of voltage divider is used to reduce the value of the input voltage to the voltage which is suitable to supply to the microcontroller.

The LM35 temp. sensor as well as the oil level measuring ultrasonic sensor, both are connected to the analog pins of the microcontroller and LCD is connected to the digital input of the microcontroller. Reset button is provided in order to reset all the values and initialize the process of simulation. The fan is installed for the cooling purpose and it will start automatically when the threshold value of temperature exceeds. The buzzer is connected to alarm about the over-heating and over-voltage of the transformer. The oscilloscope is used to show the waveform of the of the input as well as the output voltages of the transformer. In order to run the simulation, the code is written in c language and uploaded in the microcontroller.

5.2.1 Sources

We have used the variable sine voltage as the main source and input it to the main transformer. TR1 is the main transformer (Fig 5.2.1.a) which is used for the supply and TR2 is the step-down transformer (Fig 5.2.1.b) which reduces the voltage at the secondary side.

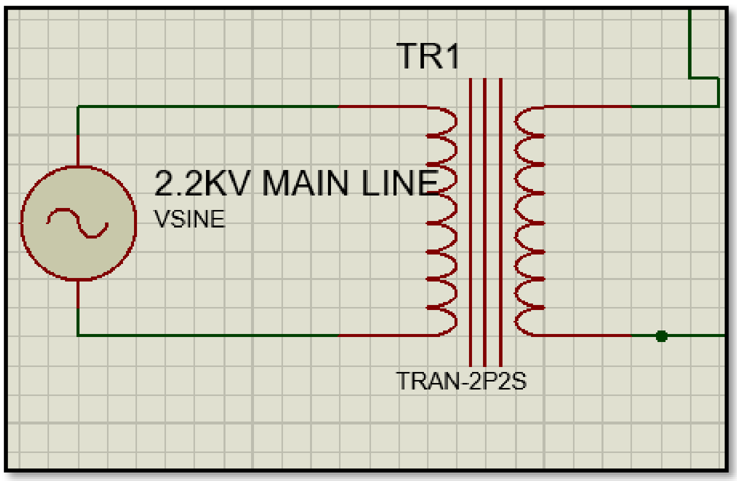

Fig 5.1 Voltage source and main transformer

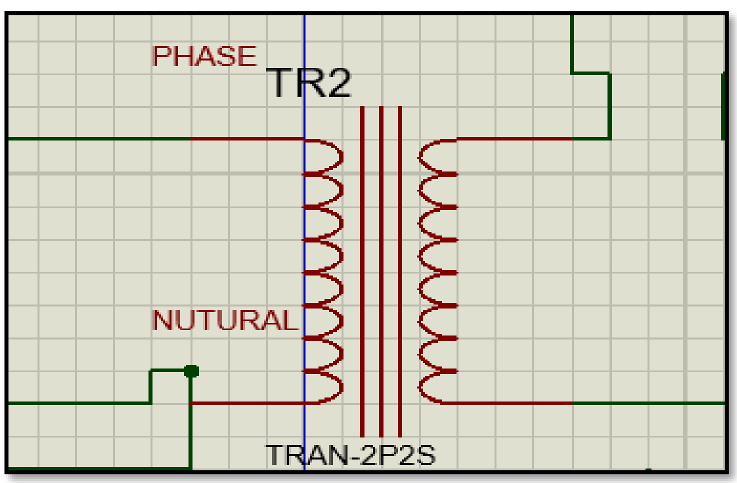

Fig 5.2 Step down transformer

5.2.2 Bridge Rectifier

This circuit changes the AC input voltage to DC output voltage. It is mainly used in the circuit of the power supplies where there is the need of DC voltage in the circuits. It is constructed using four 1N4007 diodes which are connected in series and parallel format. The capacitor of value 1000uf is connected at the end of the rectifier which is used to reduce the ripples and thus supply the smooth DC voltage.

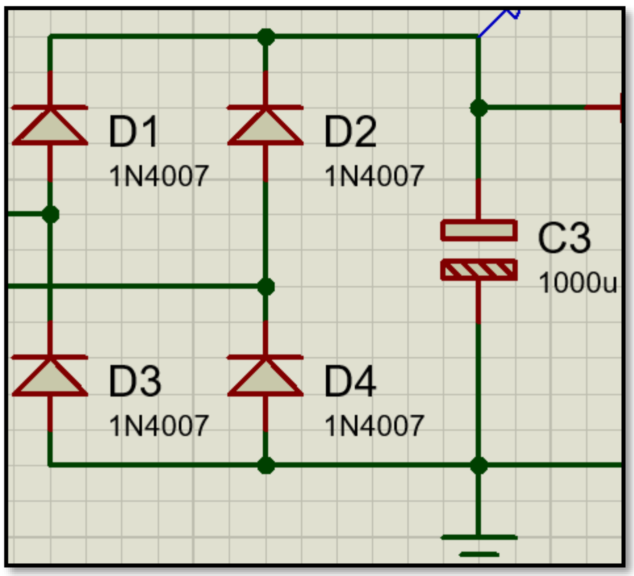

Fig 5.3 Bridge Rectifier

5.2.3 Voltage Divider

Voltage divider circuits are very important and used circuits in electronics. We have used a voltage divider circuit in order to convert the larger value of voltage to the smaller one. If we add the resistors in series and also an input voltage, then the output voltage is obtained that is very small part of the input. We have used two resisters of value 1k which are connected in series and one resister of value 500k.

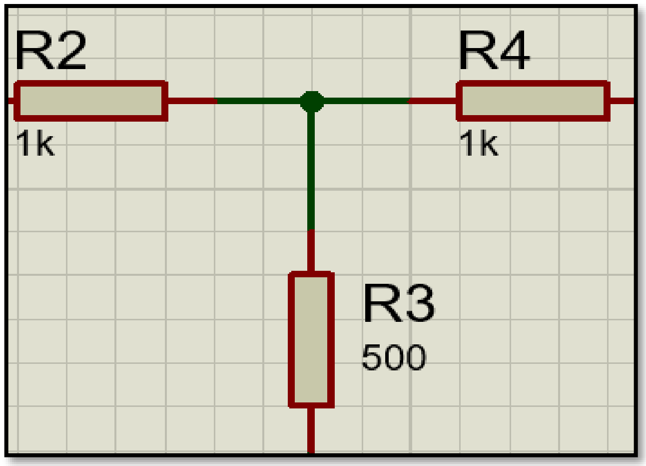

Fig 5.4 Voltage Divider Circuit

5.2.4 Oscilloscope

An Oscilloscope also known as oscillograph is used for viewing and analyzing the waveform of electrical signals by displaying it on the screen. It will graphically display the varying voltage, as 2-d plot of one or more than one signal as a function of time.

Here we are using oscilloscope in proteus 8 professional for graphical representation of voltages. so we connected the oscilloscope across input and output terminals of the transformer from which we are getting the input and output voltage waveform respectively. From the waveform we can know about the magnitude and frequency and can be varied accordingly.

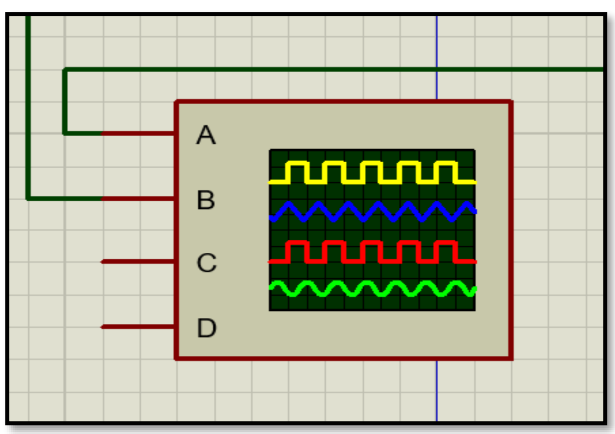

Fig 5.5 Oscilloscope in proteus simulation

5.3 Hardware Modelling

The hardware model for monitoring the parameter of the transformer have the following components –

1. Arduino Uno
2. Primary Sensing Transformer 12V 300mA
3. Thermocouple
4. Ultrasonic Sensor
5. Current Sensor
6. Switch Box
7. Three loads connected in parallel
8. LCD
9. Preset
10. Connecting wires
11. Buzzer
12. Diodes
13. Capacitors
14. White Insulation Board

The voltage is supplied through the main supply and it passes through the current sensor. The neutral wire is connected to all the loads as well as the primary sensing transformer. The main phase is supplied first to the current sensor and then from the current sensor it is connected to all the switches as well as the sensing transformer.

The voltage through the transformer is then passed to the circuit where the rectifier will convert the ac to dc voltage. Capacitor is also included further to get the smooth DC output voltage. The preset is used in order to change the resistance accordingly with the change of input voltage so that it can prevent from any damage to the circuit. The voltage divider circuit is used in order to reduce the voltage to supply it to the Arduino. The LCD is connected to the Arduino and it displays the Temperature, Voltage, Power and Oil level respectively.

The Ultrasonic sensor is connected to Arduino to measure the oil level and if the oil level falls below 51 cm, then the buzzer will start to beep and thus electrician can be alarmed instantaneously. The thermocouple which is connected to the Arduino is used to measure the temperature and when the temperature of the transformer exceeds above 40 degree Celsius, then the buzzer will beep and it will also alert the electrician. The loads here, are the incandescent light bulbs which are connected in the parallel and the ratings of each bulb is 10W, 40W, and 40W respectively. Some of the power will be consumed by the transformer as well as the circuit and when all the three loads are ON i.e. when all three bulbs are ON, then the total power will exceed 100W and it will be considered as over-load and thus the buzzer will start to beep. The top view of complete hardware model is shown in Fig 5.6.

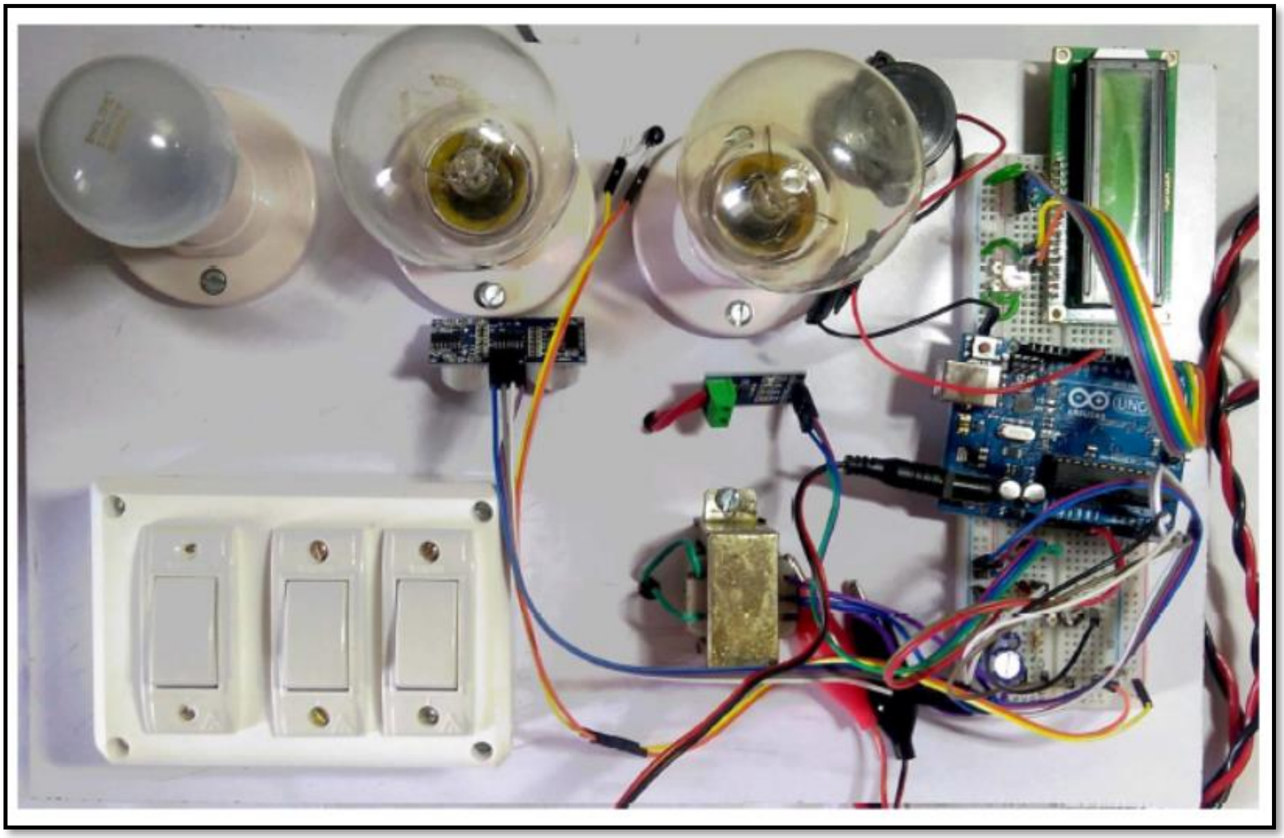

Fig 5.6 Top view of Hardware Model

5.4 Codes and Standards

Some of the public safety standards of Republic of India for the Transformers are-

- IS 5142 - (Year 1969) It tells about Continuously variable voltage auto transformers
- IS 10161, IS 10561 – (Year 1983) It is the guide which consist the application for power transformers.
- IS 11171 – (Year 1985) It tells about Dry-Type Power Transformers (IEC 60727)
- IS 12977 – (Year 1990) It tells about Arc Furnace Transformers
- IS 13956, IS 13956 – (Year 1994) It tells about Testing transformers

The Indian Standard IS:5142-1969 is used for the ratings of the voltage, frequency and output current.

The rated voltage of a continuously variable voltage auto-transformers shall be as follows-

Table 5.1 Standard ratings of Voltage

No. of Phases	Input Voltage	Output Voltage
Single Phase	240	0 to 240 or 0 to 270
3-Phase	415	0 to 415 or 0 to 470

The rated frequency shall be the standard frequency of 50 Hz.

The rated output current of the transformer shall be one of the following value-

<u>1</u>, 2, <u>2.5</u>, <u>4</u>, <u>6.3</u>, 8, <u>10</u>, <u>16</u> Amp. and their decimal multiples.

NOTE- The underlined values are the preferred rated currents.

5.5 Constraints, Alternatives and Trade-offs

5.5.1 Constraints

(1) We were not permitted to collect the data of the transformer of TNEB Vellore without official permission from the executives, thus it was time consuming.

(2) We were unable to add the library of the ultrasonic sensor, so it was not possible to measure the oil level in the simulation.

(3) Changing of loads in the main transformer and without changing the power manually, measuring the overload was not possible in PROTEUS Professional 8. Thus, we made a hardware model to demonstrate loading and overloading.

(4) The number of input parameters is limited to four due to, experimental constraints.

5.5.2 Alternatives

(1) The condition monitoring system may be modified to assess more number of transformer parameters for condition monitoring and diagnosis of all types of faults.

(2) Condition monitoring system may be made more intelligent and multiagent system with extensibility criterion and flexibility to include further interpretation techniques and monitoring technologies.

(3) In this project we did not show the real time values online. The real time online condition monitoring system can be developed for the assessment of transformer on the basis of online parameters, offline parameters and expert’s opinion.

(4) There is a huge scope in the area of online condition monitoring system using a public communication.

5.5.3 Trade-offs

The major tradeoffs in this project were:

(1) In PROTEUS Professional 8 software it is not possible to measure the oil level of the main transformer because library for ultrasonic sensor is not available.

(2) Changing of loads in the main transformer and without changing the power manually, measuring the overload was not possible in PROTEUS Professional 8 due to unavailability of sources.

(3) To measure the oil level of transformer through ultrasonic sensor and to demonstrate loading and overloading physically, we made a hardware model demonstrating the full operational characteristics of transformer and then diagnosing the transformer faults.

6. SCHEDULE, TASK AND MILESTONES

1.1 SCHEDULE

The schedule for this project work is as follows –

1. The data collection of the transformers of VIT Vellore and TNEB Gandhinagar should be completed by third week of December 2018.
2. The collection of the Oil samples and the testing of the dielectric strength of the oil should be completed by the second week of January 2019.
3. The basic understanding of the proteus software and learning about the circuit designing using this software should be done by the first week of February.
4. Simulation of the circuit, completion of the code and obtaining the waveforms using oscilloscope should be completed by the third week of February.
5. The collection of the materials to build the hardware model of transformer monitoring and the completion of the hardware model should be done by the second week of March.
6. Thesis writing, verification of the results with the respective guide and the submission of the thesis should be done by the end of March.
7. Capstone project Viva Voice Examination should be completed by the first week of April.

1.2 TASK

Table 6.1 List of Tasks

Task	Duration
Literature survey on the project	1 Week
Collecting the data of transformers of VIT Vellore	1 Week
Collecting the data of transformer of TNEB Vellore	1 Week
Collecting the oil samples	1 Week
Testing of oil samples	1 Week
Understanding about the proteus software	3 Days
Learning to make the circuit in the software	11 Days
Designing of the rectifier and the voltage divider	5 Days
Connection of analog and digital inputs to microcontroller	2 Weeks
Writing the code for the simulation to run	1 Week
Rectifying the problems in code and simulation	3 Days
Initialising the idea for hardware model	2 Days
Collecting the materials for the hardware model	1 Week
Completion of the circuit of the model	1 Week
Rectifying the constraints in the model	2 Days
Writing the code for the Arduino in hardware model	1 Week
Thesis preparation and verification with the guide	12 Days

The Gantt chart for the same has been included in Appendix A.

1.3 MILESTONES

The milestones that were achieved in this project are –

1. The completion of the data collection as well as testing of the dielectric strength of the oil within a month and a half.
2. Even without having any idea about this software in the past, we understood the basics of proteus software and the circuit designing within 2 just weeks.
3. The simulation as well as the coding part was completed within a month.
4. Initially, there was no plans to develop the hardware model but because of the problem which we were facing to analyze the real time values of the parameters in the software, we had to go through the idea of developing the hardware model and it was executed just within a month.
5. The most important part was to finish the job by writing the thesis and we completed it within just 8 days.

7. PROJECT DEMONSTRATION

7.1 Demonstration of Proteus Simulation

The complete circuit of the simulation is displayed in Fig. 7.1.

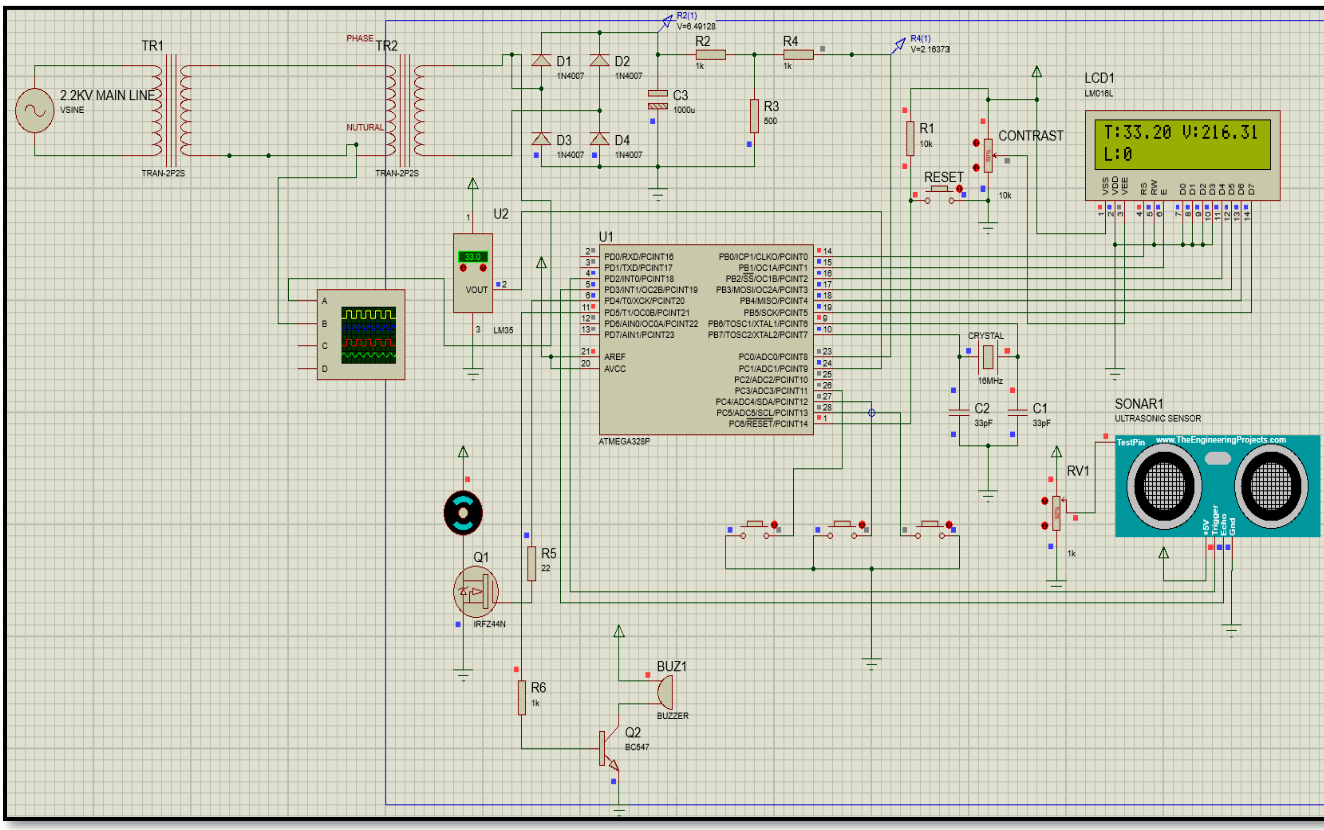

Fig 7.1 Simulation of Transformer Monitoring

The power supply is the variable voltage supply of 2.2kV which is connected to the main transformer and then the transformer TR2 step-down the voltage which passes through the bridge rectifier and convert AC voltage into DC. Then, the voltage divider circuit is used to reduce the voltage to supply it to the microcontroller. The LCD, Ultrasonic Sensor, Temperature Sensor, Cooling Fan and Buzzer are connected to the microcontroller. The code is written in order to run and execute the simulation.

Code for the simulation -

```
#include <Ultrasonic.h>

#include <LiquidCrystal.h>

#define BUZZER 5

#define FAN 4

LiquidCrystal lcd(8, 9, 10, 11, 12, 13);

Ultrasonic ultrasonic(2, 3);

void setup() {

  pinMode(BUZZER, OUTPUT);

  pinMode(FAN, OUTPUT);

  lcd.begin(16, 2);

}

void loop() {

float temperature = analogRead(1);

float volt = analogRead(0);

int level = 51 - ultrasonic.Ranging(CM);

  lcd.clear();

  temperature = temperature * 0.48828125;

  volt = volt  * 0.48828125;

  lcd.setCursor(0, 0);

  lcd.print("T:");

  lcd.print(temperature, 2);
```

```
  lcd.setCursor(8, 0);
  lcd.print("V:");
  lcd.print(volt, 2);
  lcd.setCursor(0, 1);
  lcd.print("L:");
  lcd.print(level);
  if(level < 35){
    digitalWrite(BUZZER, HIGH);
  }
  if(temperature > 40){
    digitalWrite(BUZZER, HIGH);
    digitalWrite(FAN, HIGH);
  } else if(temperature < 35){
    digitalWrite(FAN, LOW);
  }
  delay(500);
  digitalWrite(BUZZER, LOW);
  delay(500);
}
```

The waveform which is obtained through the oscilloscope is shown in Fig. 7.2.

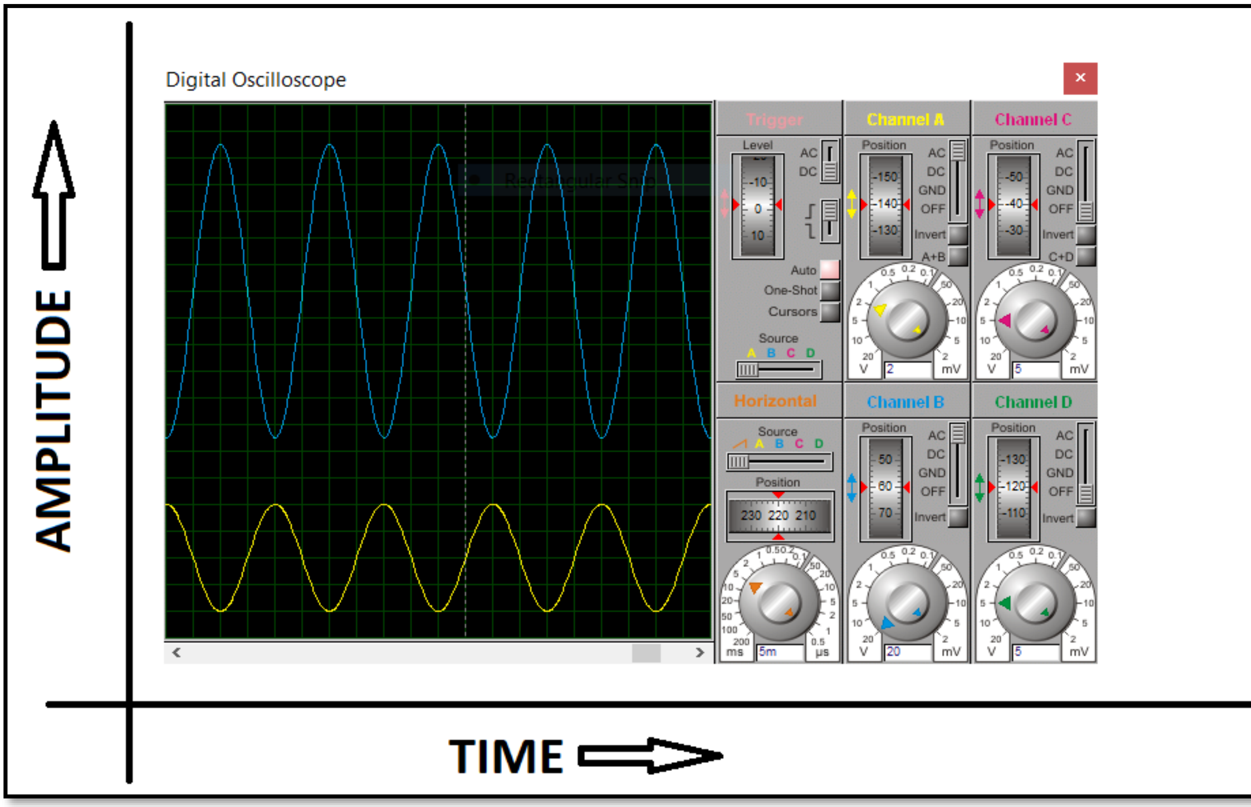

Fig 7.2 Digital Oscilloscope Output

The amplified wave which is blue in color show the voltage from the primary side of the transformer and the wave which is yellow in color represents the voltage from the secondary side. The temperature voltage will be displayed in the LCD as shown in Fig 7.3.

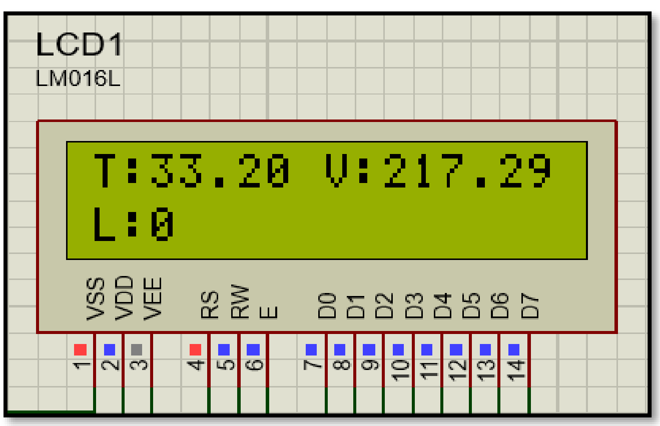

Fig 7.3 Temperature and Voltage displayed in LCD

7.2 Demonstration of Hardware Model

The real time analysis of the parameters of transformers like voltage, temperature, power and oil level cannot be performed in the simulation using the Proteus software. So, we have proposed a hardware model using which these parameters can be monitored. The LCD is connected to Arduino using 2-7 pins which displays all the four parameters. The thermocouple which is attached to A2 pin of Arduino is used for the monitoring of the temperature and the ultrasonic sensor which is plugged in to A4 and A5 pin of the Arduino is used to monitor the level of the oil in the transformer. The maximum value of temperature is set to $\mathbf{40}$℃ and if this value exceeds then it will be considered as over-heating and the buzzer will start to beep. Similarly, the level for oil is set to 51cm and if the level drops below 51 cm then also the buzzer will start to beep. The step value is calculated in order to measure the temperature and voltage in the code –

$$\boldsymbol{\delta = \frac{Vref}{ADC\ bit\ Value}}$$

where $\boldsymbol{\delta}$ is the step value and Vref is the reference voltage of 5V and ADC bit value is 1024.

The resistors used in the voltage divider circuit are of value 4.7kΩ and 1.2kΩ and the preset is used to adjust the resistance value according to the supply voltage. The voltage divider rule is used here for the voltage divider circuit to get the corresponding output voltage.

$$\boldsymbol{Vout = Vin * \frac{R2}{R1 + R2}}$$

where R1 is 4.7kΩ and R2 is 1.2kΩ and Vin will be obtained by –

$$\boldsymbol{Vin = Vdc = Vrms * \sqrt{2}}$$

where Vrms is 12V which is obtained by the primary sensing transformer used in the circuit.

Thus, the value of the output voltage is approximately 5V which is supplied to the Arduino.

There are four cases where the power will increase on increasing the load, the current will increase and thus the power will also increase and if the power exceeds 100W, then it is considered as the over-load situation and the buzzer will start to beep to alert the technicians.

CASE 1 - When no load is ON

When no load is ON i.e. no bulb is ON then the value of the voltage will be the supply voltage. It can be shown using Fig 7.4 and Fig 7.5.

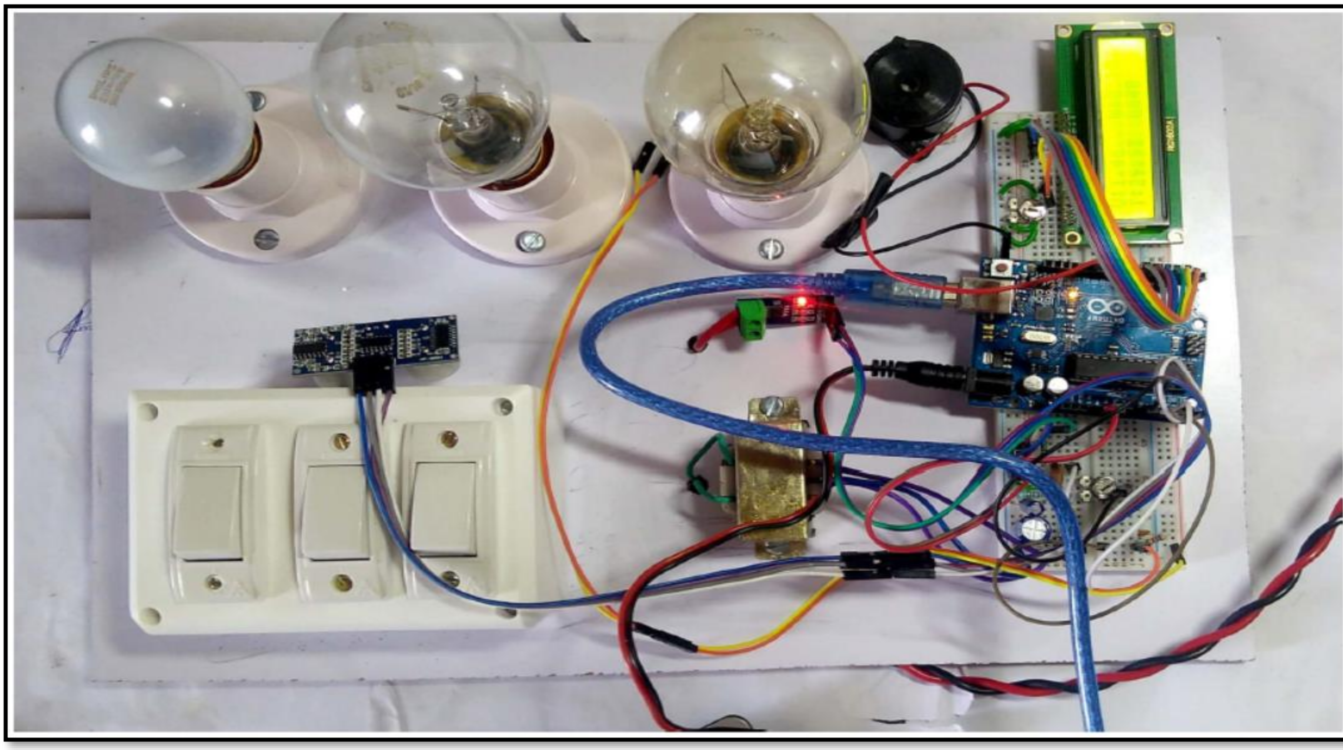

Fig 7.4 CASE 1 – When no load is ON

The corresponding output will be –

Fig 7.5 Output values when no load is ON

CASE 2- When one load is ON

When one bulb of 10W is ON, then the value of voltage will not change because the circuit is connected in parallel but the value of power will increase because of the increase in current. The same is displayed in Fig 7.6 and Fig.7.7.

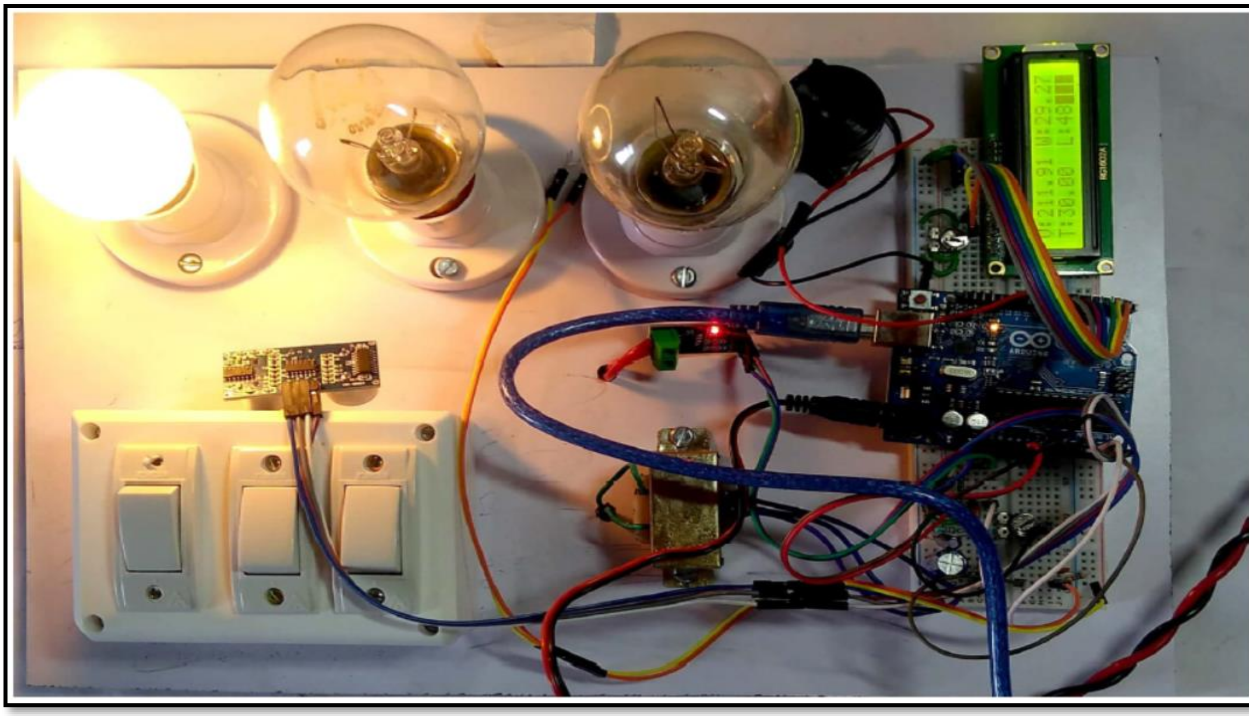

Fig 7.6 Case 2 – When one load is ON

Fig 7.7 Output values when one bulb is one

CASE 3- When two loads are ON

When two bulbs of values 10W and 40W are ON, then the power will increase due to the increase in the current. The corresponding value is shown in Fig 7.9.

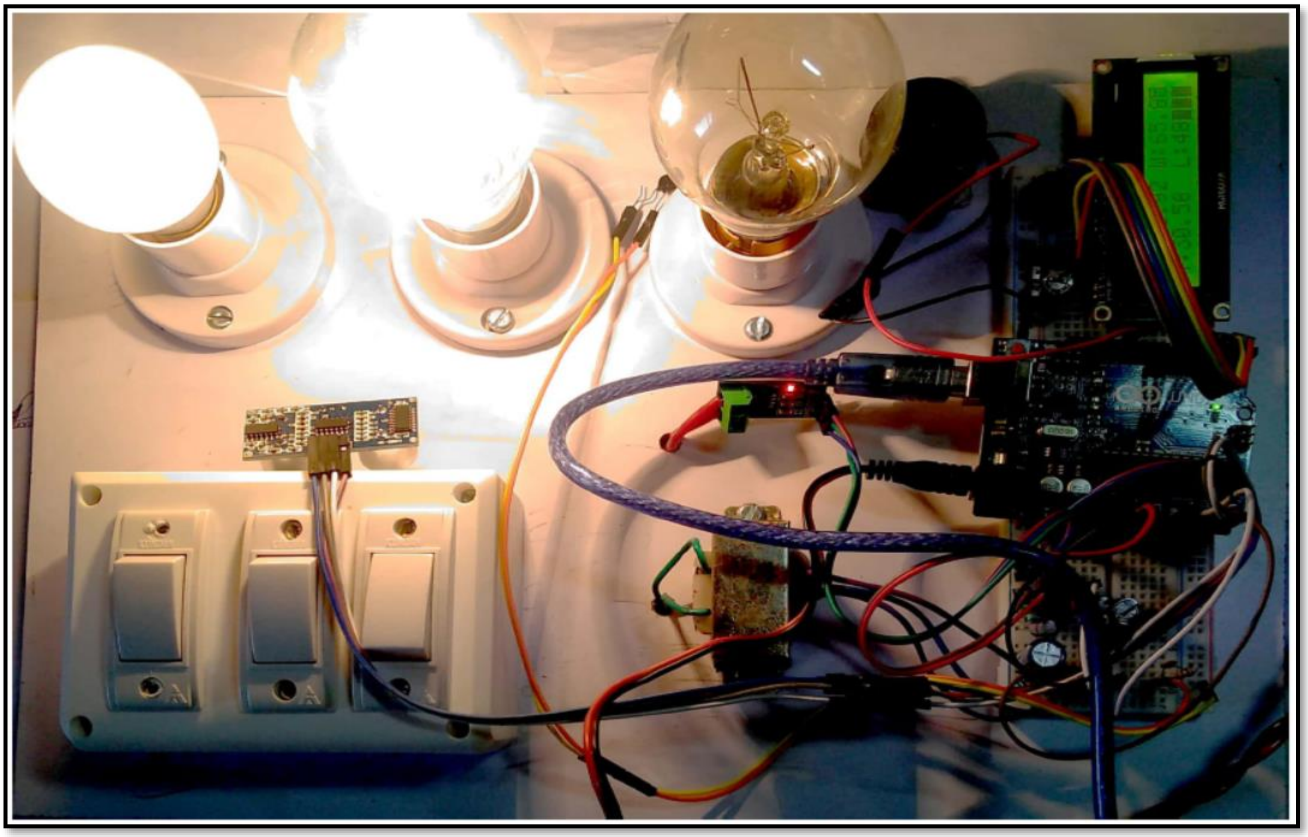

Fig 7.8 Case 3 – When two loads are ON

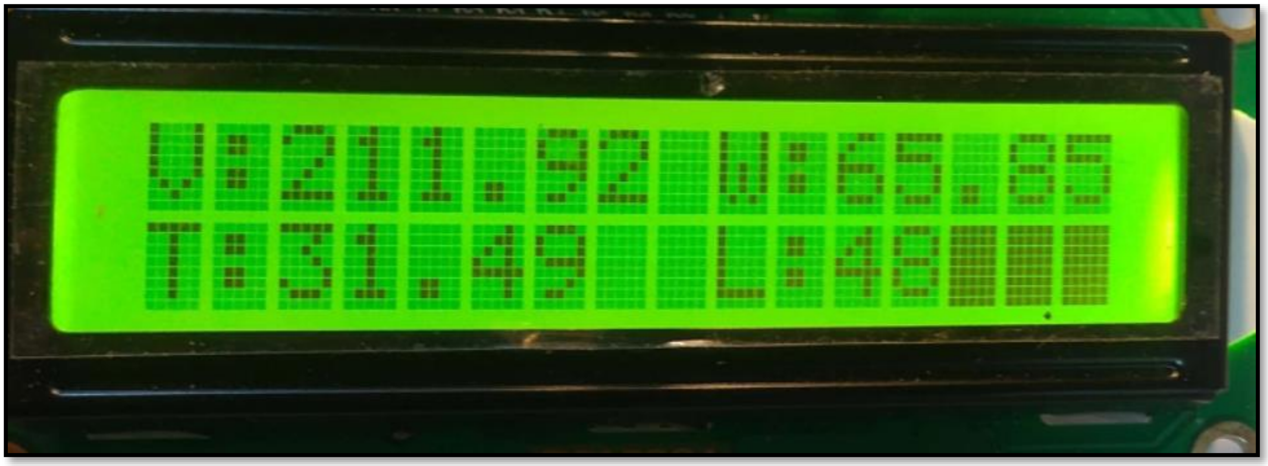

Fig 7.9 Output values when two loads are ON

CASE 4- When all the three loads are ON

When all the three bulbs of values 10W, 40W and 40W are ON, then the power will exceed 100W and then the buzzer will start to beep. The corresponding value of power is shown in Fig 7.11.

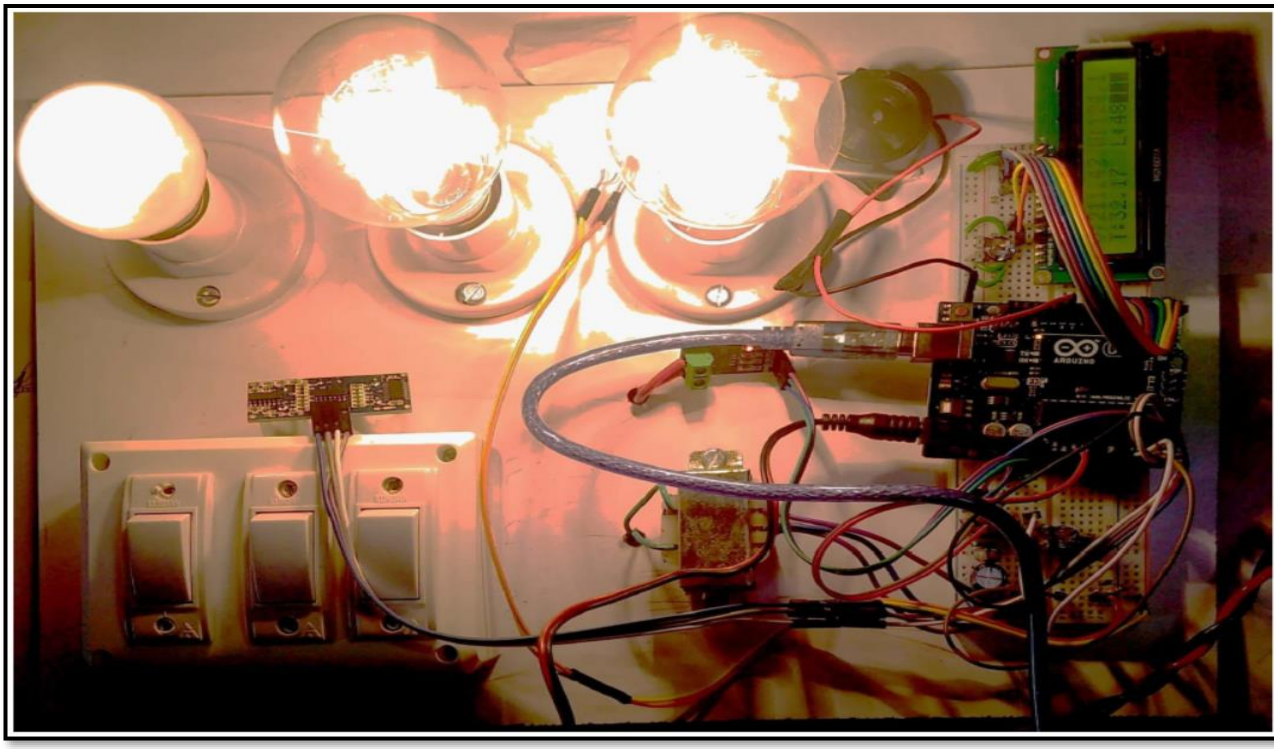

Fig 7.10 Case 4- When all three bulbs are ON

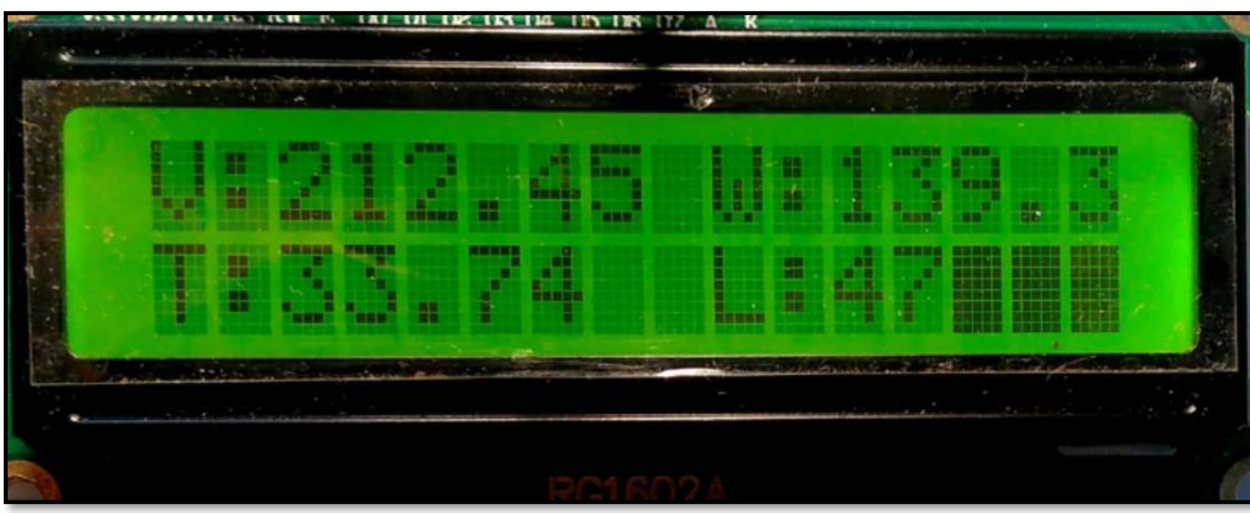

Fig 7.11 Output values when all three loads are ON

Code for the Arduino in Hardware model -

```
#include <Ultrasonic.h>

#include <LiquidCrystal.h>

LiquidCrystal lcd(2, 3, 4, 5, 6, 7);

Ultrasonic ultrasonic(A4, A5);

#define VOLT A0

#define CURRENT A1

#define TEMP A2

#define BUZZER 12

#define LED 13

#define FAN 11

void setup() {

  pinMode(BUZZER, OUTPUT);

  pinMode(LED, OUTPUT);

  pinMode(FAN, OUTPUT);

  lcd.begin(16, 2);

  lcd.print("V:");

  lcd.setCursor(9, 0);

  lcd.print("W:");

  lcd.setCursor(0, 1);

  lcd.print("T:");

  lcd.setCursor(9, 1);

  lcd.print("L:");
```

```
  digitalWrite(BUZZER, HIGH);

  delay(100);

  digitalWrite(BUZZER, LOW);

}

void loop() {

float volt = 0;

float amp = 0;

float wat;

float tmp = 0;

int level = 0;

unsigned int temp=0;

  digitalWrite(LED, HIGH);

  level = ultrasonic.Ranging(CM);

  for(int i = 0; i < 5000; i++){

    temp = analogRead(CURRENT);

    if(temp > amp){

      amp = temp;

    }

  }

  for(int i = 0; i < 500; i++){

    volt = volt + (analogRead(VOLT) * 0.48828125);

    delayMicroseconds(20);
```

```
}
volt = volt / 500;
for(int i = 0; i < 500; i++){
  tmp = tmp + analogRead(TEMP);
  delayMicroseconds(20);
}
tmp = tmp / 500;
amp = (amp / 1024.0) * 5000;
amp = (amp - 2500) / 100;
amp = amp / sqrt(2);
wat = amp * volt;
tmp = tmp / 16.13333333333333;
level = 51 - level;
lcd.setCursor(2, 0);
lcd.print(volt, 2);
lcd.setCursor(11, 0);
lcd.print(wat, 2);
lcd.setCursor(2, 1);
lcd.print(tmp, 2);
lcd.setCursor(11, 1);
lcd.print(level);
if(level < 10 || tmp > 40.0 || wat > 100){
  digitalWrite(BUZZER, !digitalRead(BUZZER));
```

```
  }else{
    digitalWrite(BUZZER, LOW);
  }
  digitalWrite(FAN, tmp > 40 ? LOW : HIGH);
  digitalWrite(LED, LOW);
  delay(400);
}
```

\

8. COST ANALYSIS

The software used for the simulation is the Proteus professional 8 and the trail version of this software can be downloaded from **https://proteus.soft112.com/** . The Hardware model required certain number of items and the cost of the items is mentioned in Table 8.1.

Table 8.1 Cost Analysis for Required items

ITEM	COST
1. Arduino Uno	Rs 400/-
2. Sensing Transformer	Rs 60/-
3. Current Sensor	Rs 200/-
4. Ultrasonic Sensor	Rs 199/-
5. Breadboard	Rs 80/-
6. Light Bulbs and Bulb holders	Rs 160/-
7. Buzzer	Rs 40/-
8. Rechargeable Li-ion batteries (6 NOS)	Rs 540/-
9. White Insulation Board	Rs 320/-
10. 10K Preset	Rs 5/-
11. 10K Thermocouple	Rs 10/-
12. Diodes 4007	Rs 5/-
13. Capacitors 1000uf	Rs 10/-
14. Switch Box	Rs 70/-
15. LCD	Rs 125/-
16. Connecting wires	Rs 80/-
TOTAL COST	Rs 2304/-

9. SUMMARY

Power transformer being important and essential device in electrical network has gained the most importance. While operation power transformer experiences the electrical, electromagnetic, thermal and mechanical stress which leads to an inchoate fault. These fault results in failure of power electrical device and failure causes unplanned outage, sudden breakdown of power transformer. This could reduce the designed life span generation of power transformer and hence value effectiveness.

A transformer has many copper windings that is connected in primary part, secondary part and the magnetic core. Primary as well as secondary windings are not connected with each other i.e. they are isolated from each other and also with the core. By the faraday's law of mutual induction transfer the power from primary side to the secondary side. Preventive observation of machine for the problems before they affect the machine can be prevented their occurrence, which are very expensive to repair and cause the loss of power offered.

The main idea of our project is to make a system that can detect the various parameters of the transformer such as voltage, power in watts, oil level and temp. with the precise wand accurate date and time of measurement. At the detection point, after receiving the information, it can be saved in the databases and also present the data on the LCD for further studies. We proposed a system that detect faults in remote transformers lines, and immediately transmit any fault information to multiple people like line man, power house, Electricity board office etc.

Since the project involves power systems, sensors and signal processing and microcontroller, we did a study on understanding how to model, simulate and connect these three different fields. This project has effectively found a way to monitor the parameters of a transformer and then alert the specific workers by producing a buzzing signal connected to the system. It can be further extended to power houses to monitor proper working of transformers.

10.REFERENCES

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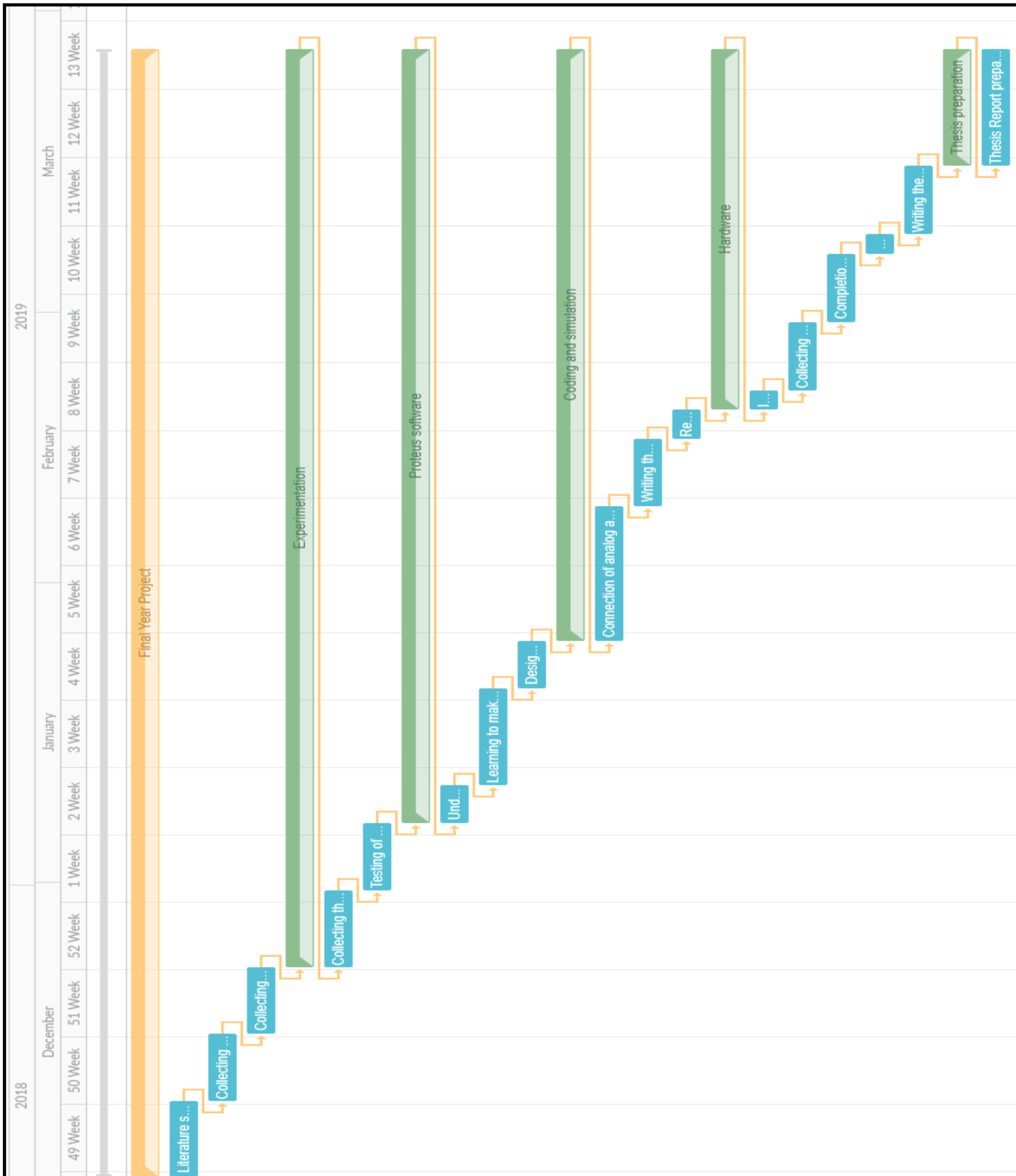
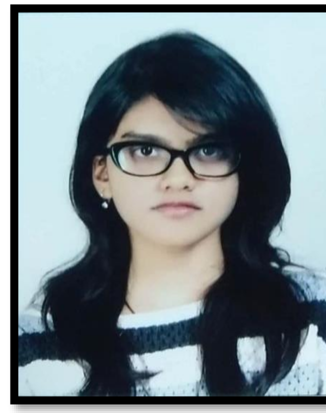
11. APPENDIX

Appendix A (Refer Section 6.2)

Table 11.1 Gantt Chart



Curriculum Vitae



Name	:	Aditi Sarkar
Father’s name	:	Adwaitya Sarkar
Date of Birth	:	16/01/1996
Nationality	:	Indian
Sex	:	Female
Company Placed	:	KPIT Technologies Ltd.
Permanent Address	:	5A Rai Mohan Banerjee Road, Bonhooghly, Kolkata, West Bengal, Pin Code- 700108
Phone Number	:	7868879293
Mobile	:	9836133853
Email id	:	meaditi333@gmail.com

CGPA: 8.53

Examinations taken:

1. GRE: NOT ATTEMPTED
2. TOEFL: NOT ATTEMPTED
3. CAT: NOT ATTEMPTED

Placement Details: KPIT Technologies Ltd.