DESIGN AND IMPLEMENTATION OF AN AUTOMATED TRANSFORMER MONITORING SYSTEM

By

Mumtahina Tasnim Purno
ID: 19321037
Shahtaz Zahra Sayeed
ID: 19121094
Faiza Ahmed
ID: 17310003
Sarthak Das
ID: 19121079
Minhajur Rahaman
ID: 18221026

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

Department of Electrical and Electronic Engineering
Brac University
September 2023

DESIGN AND IMPLEMENTATION OF AN AUTOMATED TRANSFORMER MONITORING SYSTEM

By

Mumtahina Tasnim Purno
ID:19321037
Shahtaz Zahra Sayeed
ID:19121094
Faiza Ahmed
ID:17310003
Sarthak Das
ID:19121079
Minhajur Rahaman
ID:18221026

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

Academic Technical Committee (ATC) Panel Member:

Dr. A.S. Nazmul Huda (Chair)
Associate Professor, Department of EEE, Brac University

Raihana Shams Islam Antara (Member)
Lecturer, Department of EEE, Brac University

Nahid Hossain Taz (Member) Lecturer,
Department of EEE, Brac University

Department of Electrical and Electronic Engineering Brac University
September 2023

Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

Mumtahina Tasnim Purno
ID:19321037

Shahtaz Zahra Sayeed
ID:19121094

Faiza Ahmed
ID:17310003

Sarthak Das
ID:19121079

Minhajur Rahaman
ID:18221026

Approval

The Final Year Design Project (FYDP) titled "Design and Implementation of An Automated Transformer Monitoring System" submitted by

1. Mumtahina Tasnim Purno (19321037)
2. Shahtaz Zahra Sayeed (19121094)
3. Faiza Ahmed (17310003)
4. Sarthak Das (19121079)
5. Minhajur Rahaman (18221026)

of Summer, 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 26 August 2023.

Examining Committee:

Academic Technical Committee (ATC): (Chair)

____

Dr. A.S. Nazmul Huda
Associate Professor, Department of EEE
Brac University

Final Year Design Project Coordination Committee: (Chair)

____

Dr. Abu S.M. Mohsin
Associate Professor, Department of EEE
Brac University

Department Chair:

____

Dr. Md. Mosaddequr Rahman
Professor, Department of EEE
Brac University

Ethics Statement

The similarity index result of this report is 17%.

Abstract/ Executive Summary

The main objective of the project is to design and build a transformer monitoring system for the protection of transformer faults. The present monitoring system requires time-consuming human interaction and is difficult to predict when problems may materialize. In this project, we used the Arduino micro controller to build a system for automatically monitoring and protecting the transformer. The system would also provide real-time transformer parameter monitoring. The real-time monitoring of transformer and gas sensor voltage, current, oil levels, and temperature is covered in this article. Effective control measures, which are also addressed, can be used to manage the load voltage in an excessive voltage situation. The values at that moment will be continuously compared by these devices to the values that were previously specified.

Keywords: Transformer; Arduino; Protection; Monitoring System

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

The most crucial component of the electrical system is the transformer. It must thus be kept in top condition and under close observation. The main issues with the system might be brought on by a flaw or imbalance in the transformer. As a result, in this case, our objective is to build a system that would constantly check the transformer and respond appropriately if there is an imbalance. The system would also enable real-time monitoring of transformer properties, including voltage, current, temperature, and others, on an Android smartphone and desktop PC and provide notifications in the case of issues. Our project is focused on constructing an automated transformer monitoring and protection system utilizing an Arduino micro controller.

This study seeks to streamline and enhance the system. Automated systems take the place of conventional methods. Although monitoring is necessary for human existence, it is also quite time-consuming and labor-intensive. Modern technologies may be added to this process to make it better. Because V&I supplies are already scarce, mankind must take urgent measures to protect them. The proposed approach saves time since it necessitates the least amount of supervision. Since our system is automated, it even eliminates the need for maintenance staff.

With the growth and expansion of the national economy and power system, reliability and safety concerns for the power system have become increasingly crucial [1]. If we think about the things we do daily, we can realize that electricity plays a significant role in our lives and that transformers are how energy is brought to us from power plants. The transformer is essential to the electricity distribution system. The protection of transformers is therefore essential. Transformers are used in a range of projects, from small ventures to large corporations [5]. Due to the growing population and machinery, there is an increase in power consumption [4]. Unauthorized electricity use causes transformers to become overloaded. Overload influences the efficiency of both the energy distribution system and the transformer. As a result, the designed system provides automatic load separation to protect the transformer from overloading-related damage. A suggested approach was used to build a micro controller-based transformer with overload protection. The micro controller-based relay provides self-monitoring capabilities, as well as more adjustable features, high accuracy, flexibility, and a larger range of setup possibilities.

1.1.1 Problem Statement

Precision, trustworthy problem detection mechanisms, real-time data monitoring, and short response times are required in modern power systems. The proper operation of the distribution transformer is crucial to the dependability of the power system. Real-time data monitoring, abnormal condition detection, fast processing speed, low installation and maintenance costs, and more adaptability are all advantages of a micro controller-based system.

1.1.2 Background Study

Power system reliability and safety concerns have become increasingly significant as the national economy and power system have progressed and developed [1]. Looking back at our daily lives, we may infer that electricity is an integral part of our lives, and transformers serve as electrical carriers from generation stations to us. The transformer is a critical component of the power distribution system. As a result, transformer protection is critical. Transformers are employed in a wide range of applications, from tiny initiatives to large businesses. Power is becoming increasingly scarce as the world's population and machinery grow. Due to improper electricity consumption, transformers get overloaded. The effectiveness of the transformer and the electrical distribution system are both impacted by overload. As a result, the created system has automated load isolation to stop overloading from damaging transformers. This leads to the recommendation of a design approach for an overload-protected micro controller-based transformer. With different features, including self-monitoring and checking using GSM technology, the micro controller-based relay offers more adjustable properties, more precision, more flexibility, a larger selection of configuration possibilities, and a smaller, cheaper cost.

A system based on the micro controller is suggested to monitor and safeguard the substation transformer from current rise due to overload. A PLC-based automated control system was recommended to be used [2], [3] to monitor and detect both internal and external transformer problems. A defensive system including a temperature sensor, microprocessor, LCD, GSM, and XBEE was suggested to convey the notice to the electrical board. It has been customary to utilize a fault detection method for transformer protection. [10]. Because of the enhanced advantages, researchers are currently devoting attention to transformer failure monitoring based on vibration analysis. Even though the outcomes of this method are outstanding, it may still be improved by using algorithms to analyze the data and find the flaws.

Prior until today, various advances in relay design have been achieved to overcome restrictions, such as those to increase the number of analog inputs, implement a CT saturation countermeasure, and run differential relays at high speeds [4]. Using previous methodologies, we were able to investigate a variety of difficulties. CT saturation must be considered for differential protection. If the CT is saturated due to an external fault, the current does not flow during the non-saturation period. As a result, digital relays were used as a safety measure. To solve the specific protection and control challenges, digital relays were used on the distribution side of the line. Compared to analog relays, digital relays provide several advantages. These days, digital multi function relays are often employed because of their dependability, versatility, and low cost. Sometimes differential relay protection will not work. Inrush current in the transformer at starting is suspected as being the root of this problem. The per-phase approach, cross-blocking method, % average blocking method, and harmonic sharing method were among the techniques used. Fuzzy ways of protection were developed, which were more sophisticated than earlier methods, to prevent such faults and protect the transformer [5].

1.1.3 Literature Gap

We go through our system overview in this chapter. It facilitates the achievement of the intended objectives by ensuring the effective completion of the work. Since a few years ago, there have been many advancements made in hardware and communication technology, which has made it a very intriguing topic. We will discuss some earlier reviews of the literature related to our topic in the section below.

A system based on a micro controller is developed to monitor and safeguard the substation transformer against current surges caused by overload [1]. It was recommended that a PLC-based automated control system [2, 3] be used to monitor and detect internal and external transformer problems. A defensive system using a temperature sensor, micro controller, LCD, GSM, and XBEE was suggested in [4] to convey the notice to the electrical board. A conventional fault detection technique [5] has been utilized for transformer protection. Because of the enhanced benefits, researchers are currently focusing on transformer failure monitoring using vibration analysis.

This approach produces good results, but it may be enhanced by utilizing computer algorithms to evaluate the data and forecast the defect. This paper describes the creation of an IoT-based system for real-time monitoring and control of transformer parameters. This system is installed near the transformer, and the parameters under consideration are diagnosed and transferred to a centralized web server. As a result, the data is used to determine the state of the transformer in real-time and is saved in a server database for future examination. Up to the present day, various advancements have been seen in the construction of relays to overcome constraints, including an increase in the number of analog inputs, a CT saturation countermeasure, and high-speed differential relay operation [2]. Earlier approaches allowed us to use surveys to investigate a wide range of issues. CT saturation must be taken into consideration for differential protection. If CT saturation happens when there is an external fault, the current does not flow during the non-saturation interval. Digital relays were therefore used as a kind of protection.

To solve the specific protection and control challenges, digital relays were used on the distribution side of the line. Digital relays provide advantages over analog relays, which were formerly used. Digital multi-function relays predominate nowadays because they are durable, multifunctional, and inexpensive [3]. Differential relay protection can occasionally fail. This problem is suspected to be caused by an inrush current in the transformer at the start. The per-phase technique, the cross-blocking method, the percent average blocking method, and the harmonic sharing method were all used. To overcome this issue and protect the transformer, protection using fuzzy techniques, which were more advanced than previous methods, was developed [4]. The Internet of Things is being used by industries and nearly everywhere.

1.1.4 Relevance to current and future Industry

The design and implementation of an Automated Transformer Monitoring System (ATMS) is extremely important in both existing and future industries, particularly in the context of power production, transmission, and distribution. Here is a rundown of its significance:

- Increased dependability and Reduced Downtime: In today's electricity industry, dependability is critical. ATMS provides real-time monitoring capabilities, allowing for the early discovery of issues such as transformer overheating, oil deterioration, or insulation concerns. This proactive strategy enables prompt maintenance and repair, saving downtime and assuring continuous power supply. ATMS is critical in an era when companies rely largely on uninterrupted electricity.
- Increased Efficiency: Using ATMS allows for more efficient resource utilization. Maintenance activities, rather than routine inspections, may be scheduled based on the actual transformer state, saving time and resources. This efficiency is crucial for businesses looking to enhance operations, save costs, and maximize profits.
- Enhanced Safety: Transformers are critical components in power systems, and failures can have severe consequences. ATMS offers another layer of security by continuously monitoring parameters and triggering alarms or shutdowns when

irregularities are detected. This aspect of safety is becoming increasingly important for firms with stringent safety regulations.

- Smart Grid Integration: The continuing shift to smart grids requires enhanced monitoring and control systems. ATMS can interface smoothly with smart grid infrastructure, providing real-time data that allows utilities to make educated decisions regarding power distribution, load balancing, and system stability. This connection is critical for energy management and sustainability in the future.
- Data-driven insights: As industries expand, data becomes increasingly useful. ATMS generates a variety of data that may be used to forecast maintenance, analyze trends, and optimize systems. This data-driven strategy is consistent with the emerging trends of Industry 4.0 and the Industrial Internet of Things (IoT).

1.2 Objectives, Requirements, Specification, and constants

1.2.1. Objectives

Creating a conceptual framework for the power transformer monitoring system, which will include hardware and software components, communication protocols, and data-gathering processes. Depending on the demands of the power transformer monitoring system, this may entail selecting appropriate sensors, data-gathering systems, and communication interfaces. Installing a data collection system to gather real-time data from the power transformer, such as temperature, oil level, moisture, and other pertinent characteristics. Creating algorithms or models that analyze and extract useful information from acquired data, such as fault detection, condition assessment, and predictive maintenance.

Integrating the proposed monitoring system with the infrastructure already in place for power transformers, including communication networks, SCADA systems, and other monitoring and control systems. Make sure that the new system is compatible and seamlessly integrates with the current power grid. identifying current research, methods, and technologies for power transformer monitoring systems by doing a thorough literature study. By doing so, it will be possible to assess the status of the field at the moment and spot any gaps or restrictions that need to be filled. Use lab tests, computer simulations, or field experiments to assess the proposed power transformer monitoring system's performance. evaluating the developed system's performance in comparison to existing methods or standards to confirm its effectiveness and efficiency in keeping track of the health of power transformers. Identifying and suggesting optimization options or upgrades to increase performance, accuracy, reliability, and cost-effectiveness in the designed power transformer monitoring system. This may require proposing innovative ideas or methods to existing constraints or difficulties.

Transformer protection is employed to spot unusual circumstances and protect the transformer from both internal and external flaws. The main objective is to protect the transformer and transmission line in a way that is safe and secure and poses low risk to human life [2]. The system will thus automatically do the comparison between the set value and the incoming values and take the necessary action. Real-time detection and monitoring of essential electrical parameters, such as voltage, current, harmonic component, power, and power factor, as well as non-electrical data, such as temperature, internal pressure, and oil level, are necessary for power transformer monitoring [4]. The monitoring system is made even more effective by including a control mechanism that enables it to disconnect the transformer from the electrical grid in case of an emergency. The readings from the moment the issue started to the fault being cleared can be recorded on a cloud service that the relevant authority team can view. This will contribute to the security of grid improvements in the future. Utility firms deal with a variety of challenging issues [2], not simply those that include transformers, such as monitoring and safeguarding them. In smart metering systems, where meters are equipped with telecommunication modems and can be read or controlled remotely, the installation position of transformers is also taken into consideration [3]. In this project, a current transformer, a step-down potential transformer, and a micro controller will all be used [4]. Then, a range of sensors will be used to determine the temperature and oil condition of a transformer. Temperature, gas, and oil level sensors are examples of similar sensors. To convert the AC voltage to the DC voltage, we must use a rectifier in this instance. We need to use a capacitor that will act as a filter since the rectifier's pulsating DC voltage requires it.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements

- ❖ **Data processing:** The system ought to be capable of gathering information on vital variables like temperature, oil level, winding currents, and voltage.
- ❖ **Real-time monitoring:** The system must be able to track transformer performance in real-time and identify any problems or anomalies as they arise.
- ❖ **Remote access:** The system ought to be able to be accessed from a distance, allowing technicians to identify problems and fix them without having to physically enter the transformer.
- ❖ **Alarms and notifications:** When faults or abnormalities are found, the system should be able to send out alarms and notifications so that maintenance staff can react quickly and efficiently.
- ❖ **Data analysis:** To help maintenance staff make data-driven decisions, the system should be able to analyze the gathered data to find trends and patterns in transformer performance.
- ❖ **Reporting:** The system should be able to produce reports on the performance of the transformers, giving useful information on performance trends and pointing out potential areas for improvement.

Non-functional requirements

- **Reliability:** To ensure that problems are quickly identified and fixed, the system should be dependable with a high level of availability and uptime.
- **Security:** The system needs to be safe, with the right safeguards in place to prevent unauthorized access and guarantee data confidentiality.
- **Scalability:** As the number of transformers being monitored rises, the system should be scalable and capable of handling growing data loads.
- **User-friendliness:** The system should have an easy-to-use interface that is simple and intuitive for maintenance staff to operate.

- **Interoperability:** The system should be able to communicate with and integrate with other electrical power system systems and technologies.
- **Maintenance:** The system should be simple to maintain, requiring little downtime for tasks like updating software or fixing hardware.

1.2.2 Specifications

Table 1.1: Specification: System & Component level

System Level	**Component Level**
Transformer Monitoring System.	• Temperature Sensor. • Ultrasonic Sensor. • GAS Sensor. • Voltage Sensor. • Current Sensor.
Controller Section	• Arduino • Node MCU • Relay
Hardware systems	• PVC Board. • Switch. • Socket.
Algorithm Development and Coding	• Programming C++ • Arduino Software IDE.
Power unit and Output	• SMPS. • LCD Display.

Table 1.2: Component Details

Components	**Details**	**Purpose**
SMPS (Switch Mode Power Supply)	• Input Voltage: AC 100 - 264V 50 / 60Hz • Output Voltage: 5V DC, 5A • Protections: Overload / Over Voltage / Short Circuit • Auto-Recovery After Protection • Universal AC input / Full range • 100% Full Load Burn-in Test • Cooling by Free Air Convection • High Quality and High Performance • LED power supply with a metal body for hidden installation for LED lighting	Power Supply to the prototype
Arduino Nano	• Microcontroller ATmega328 • Architecture AVR • Operating Voltage 5 V • Flash Memory 32 KB of which 2 KB used by the bootloader • SRAM 2 KB • Clock Speed 16 MHz • Analog IN Pins 8 • EEPROM 1 KB • DC Current per I/O Pins 40 mA (I/O Pins) • Input Voltage 7-12 V • Digital I/O Pins 22 (6 of which are PWM) • PWM Output 6 • Power Consumption 19 mA • PCB Size 18 x 45 mm • Weight 7 g	The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P.used for the main controller of this project.
Node MCU	• Wi-Fi Module – ESP-12E module like ESP-12 module but with 6 extra GPIOs. • USB – micro-USB port for power, programming, and debugging • Headers – 2x 2.54mm 15-pin header with access to GPIOs, SPI, UART, ADC, and power pins • Misc – Reset and Flash buttons • Power – 5V via micro-USB port • Dimensions – 49 x 24.5 x 13mm	The Node MCU ESP8266 development board. Used for data transmission in a Cloud server.
Temperature Sensor DHT11	• Operating Voltage: 3.5V to 5.5V • Operating current: 0.3mA (measuring) 60uA (standby) • Output: Serial data • Temperature Range: 0°C to 50°C • Humidity Range: 20% to 90% • Resolution: Temperature and Humidity both are 16-bit • Accuracy: ±1°C and ±1%	This DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor that used for monitoring of transformer Temperature.

GAS Sensor MQ-2	● Operating Voltage: +5V ● Preheat Duration:20 s ● Analog Output Voltage:0 to 5 V	To monitor the gas or smoke of the transformer.
Voltage Sensor	● Onboard precision micro voltage transformer ● High precision op-amp circuit board, do accurate sampling for the signal and appropriate compensation, and other functions ● Within 250 v ac voltage can be measured, the corresponding output analog quantity can be adjusted ● PCB board size: 49.5 (mm) x19.4 (mm)	To measure of transformer input/output voltage level.
Current Sensor	● 30A Range ACS712 Module ● Current Sensor for Arduino ● The current sensor chips: acs712elc20a; ● Pin5 V power supply on board power indicator	To measure of transformer input/output current level.
Ultrasonic Sensor	● Affordable Price ● Operating Voltage: 5 V ● Sonar Sensing Range: 2-400 cm ● Max. Sensing Range: 450 cm ● Frequency: 40 kHz	To use for oil level of transformer.
LCD Display	● 16 characters wide, 2 rows ● Black/White text on the yellow/blue background ● Single LED backlights included can be dimmed easily with a resistor or PWM. ● Can be fully controlled with only 6 digital lines! (Any analog/digital pins can be used)	All the data shown in LCD Display.
Transformer	● Input Voltage: 230V AC ● Output Voltage: 12V or 0V ● Output Current: 1 Amp ● Soft Iron Core. ● 1 Amp Current Drain.	Here the transformer is the core component of this project
SIM900D	● Frequency Bands: SIM900D supports quad-band GSM/GPRS 850/900/1800/1900 MHz frequencies. It can be used in any region around the world where these frequencies are supported. ● Dimensions: The module has a small form factor of 33mm x 33mm x 3mm, making it suitable for use in applications where space is limited. ● Interfaces: SIM900D features an industry-standard interface, including UART, USB, and audio interfaces. It also has a SIM card socket and supports a variety of AT commands for communication. ● Power Consumption: The module has low power	The SIM900D is a quad-band GSM/GPRS module designed for M2M (machine-to-machine) and IoT (Internet of Things) applications.

	consumption, making it ideal for use in battery-powered devices. It consumes less than 1 mA in sleep mode and less than 200 mA in active mode. ● TCP/IP Protocol Stack: SIM900D has an embedded TCP/IP protocol stack, allowing it to communicate with other devices over the internet. It also supports HTTP, FTP, and SMTP protocols. ● Voice and Data Services: The module supports voice, SMS, data, and fax services over the GSM/GPRS network. It also has a built-in microphone and speaker for voice communication. ● Certifications: SIM900D is certified by regulatory bodies such as CE, FCC, and RoHS, ensuring compliance with international standards for safety and environmental protection.	

1.2.3 Technical and non-technical Considerations and constraints in design process

- **Additional funding:** Every project, regardless of size or complexity, requires additional funding. A project might need extra materials, like extra personnel or equipment, both of which might need extra funding to acquire. Unexpected costs, like cost overruns or delays, may arise during projects, necessitating the allocation of additional funds to keep the project on schedule. Occasionally, it may be necessary to alter a project's scope due to unforeseen circumstances or adjustments to the requirements. Therefore, it is likely that additional funding will be required to support the expanded scope.
- **Failure of the Network:** If our network fails, the entire effort will be in vain. Throughout this project, we will receive updates on the state of our transformer. We cannot take the necessary precautions to prevent it from happening when the network is down because we are unable to receive the update. As a result, the failure of our network severely restricts the scope of our project.
- **Issue Having obtained consent from the neighborhood:** Residents might be concerned about their privacy, particularly if the monitoring system makes use of cameras or sensors. To solve this issue, it is essential to effectively communicate the system's objective and the steps involved in its implementation. It might also be beneficial to provide assurances that the system won't be used for other purposes and that the data gathered will be kept private. It's possible that someone would need permits and must follow specific regulations depending on the area. Before putting the monitoring system into place, it is essential to research these requirements and make sure all required approvals have been obtained.
- **Security and maintenance:** Make sure the monitoring system's data is encrypted to prevent access from outside parties. Security and maintenance. You can manage who has access to the system and what they can do after logging in by configuring access limits. By restricting access and limiting the use of the monitoring device, the hardware of the monitoring system is secured. Conduct routine audits to keep an eye out for security issues and to quickly address them. The transformer monitoring system needs to be visually inspected frequently to ensure proper operation. Look for physical damage, loose connections, corrosion, and rust in the equipment. To prevent any dust

or debris from affecting the measurements, the sensors, and other equipment must be kept clean. Cleaning regularly will help you avoid system issues and failures. By keeping up with software updates, the system will always be running the most recent version. This can prevent any compatibility issues and ensure the security of the system from any potential online threats. To ensure that the system is gathering the right data and that the values are within acceptable ranges, data analysis should be done regularly. Any irregularities should be investigated and corrected. Training must be provided to the group in charge of operating and maintaining the transformer monitoring system. They will be able to identify and address potential issues more effectively if they do this. Documenting all maintenance activities should include any repairs or equipment replacements. The system performance can then be observed for trends and patterns.

- **Changes in the Demands of Client:** Customers are almost always won over by the superior product. They have shifting needs as a result. So it follows that we must comprehend what the customer wants to meet their needs. The status of our project must also be continually checked.
- **Technology Adaptation:** Using technology regularly or having grown up around it may make it easier to get used to new technologies. Even simple tasks could be difficult for a non-technical person. For newcomers, new technology might be unsettling. When trying something new, some people may experience anxiety, which makes learning and adapting difficult. Complex technology knowledge is required. Due to networking, security procedures, and camera placement, setting up and using a home security system can be difficult. Inaccessible technology may make it difficult for people with disabilities to use it.

1.2.4 Applicable compliance, standards, and codes

Table 1.3: Applicable Standards and Codes

Code	Standard Name	Definition
IEEE C37.91-2021 [5]	IEEE guide for protecting power transformers	This document offers protection engineers and other readers instructions for safeguarding three-phase power transformers with rated capacities greater than 5 MVA and operating at voltages greater than 10 kV. There is additional information to help protection engineers utilize relays and other devices to safeguard transformers used in transmission and distribution networks.
PC57.143 [7]	Guide for application of monitoring equipment to liquid immersed transformer and components	The important metrics that may be examined to get a read on the health of liquid-immersed transformers are identified in this guide. Additionally, it addresses the use of sensors, risk/benefit analysis, and monitoring systems. The interpretation of monitoring findings is not covered in this handbook.
IEEE C37.241-2017[8]	IEEE guide for application of optical instrument transformers for protective relaying	The use and usage of optical voltage and current sensor systems for protective relaying are discussed, together with advice on sensor selection, installation, testing, and operation. On this page, you may find out more about optical voltage and current sensing methods as well as a variety of performance metrics, such as accuracy, bandwidth, noise, stability, and the effects of temperature and vibration.
PC57.141[6]	Guide for detection monitoring and evaluation of winding deformation in liquid-immersed power transformer	This manual offers information on winding deformation detection, monitoring, and assessment for liquid-immersed power transformers rated at 69 kV and above. It consists of the following elements: basic specifications, detection techniques, and procedures for condition assessment for the detection and monitoring of transformer winding deformation caused by vibration.
IEEE 802.11-2016[8]	IEEE Standard for Information Technology Telecommunication and information exchange between systems a local and metropolitan area network specific requirement, part-11: wireless LAN medium access control (MAC) and physical layer (PHY) specifications	This revision specifies improvements to the current medium access control (MAC) and physical layer (PHY) functions as well as technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs).

1.3 Systematic Overview/summary of the proposed project

This system uses a network of sensors to continuously monitor crucial parameters like temperature, oil quality, and load conditions. Real-time data processing allows for the early detection of anomalies and potential difficulties. Through predictive analytics and remote access, it enables informed decision-making, proactive maintenance scheduling, and downtime minimization. This methodical approach finally facilitates the efficient and sustainable functioning of transformer assets, while also improving operational dependability, lowering maintenance costs, and aligning with the emerging trends of data-driven industrial processes.

1.4 Conclusion

To sum up, a proactive approach to transformer management, an automated transformer monitoring system is a vital instrument that combines data collecting, processing, communication, and predictive analytic to guarantee the dependable and effective operation of transformers.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

We have a choice of designs to construct a prototype. We uncover two potential solutions to the problem here.

2.2 Identify the design approaches

- Arduino Microcontroller Based Transformer Monitoring System
- AI/ Raspberry Pi Based Transformer Monitoring System

2.3 Describe multiple design approach

- Arduino Microcontroller-Based Transformer Monitoring System:

The Arduino Microcontroller Based Transformer Monitoring System is a cutting-edge technological application in the field of electrical engineering. This system takes advantage of the adaptability and accessibility of Arduino micro controllers to develop a low-cost and efficient solution for transformer monitoring. It offers real-time data collection by combining sensors and communication modules, allowing operators to precisely monitor important factors such as temperature, oil condition, and load changes. This data-driven strategy not only improves transformer dependability but also enables predictive maintenance, lowering downtime and operational expenses. With its user-friendly interface and versatility, this system has great potential for assuring optimal transformer performance and lifetime in a variety of industrial and power distribution scenarios.

- AI/ Raspberry Pi Based Transformer Monitoring System:

The Raspberry Pi Based Transformer Monitoring System is a game changer in transformer management. This system, which makes use of the processing capabilities of the Raspberry Pi, provides a versatile and cost-effective solution for real-time monitoring and analysis of crucial transformer characteristics. It is outfitted with a variety of sensors and communication modules that continually gather and process data on variables including temperature, oil quality, and load conditions, offering crucial insights into the transformer's health and performance. Its flexibility and interoperability with a wide range of software applications make it an excellent solution for enterprises looking to improve transformer reliability, save maintenance costs, and optimize power distribution networks. The Raspberry Pi-based system highlights the confluence of low-cost computer technology with transformer management, offering up new options for data-driven transformer control.

2.4 Analysis of multiple design approach

Arduino Microcontroller Based Transformer Monitoring System

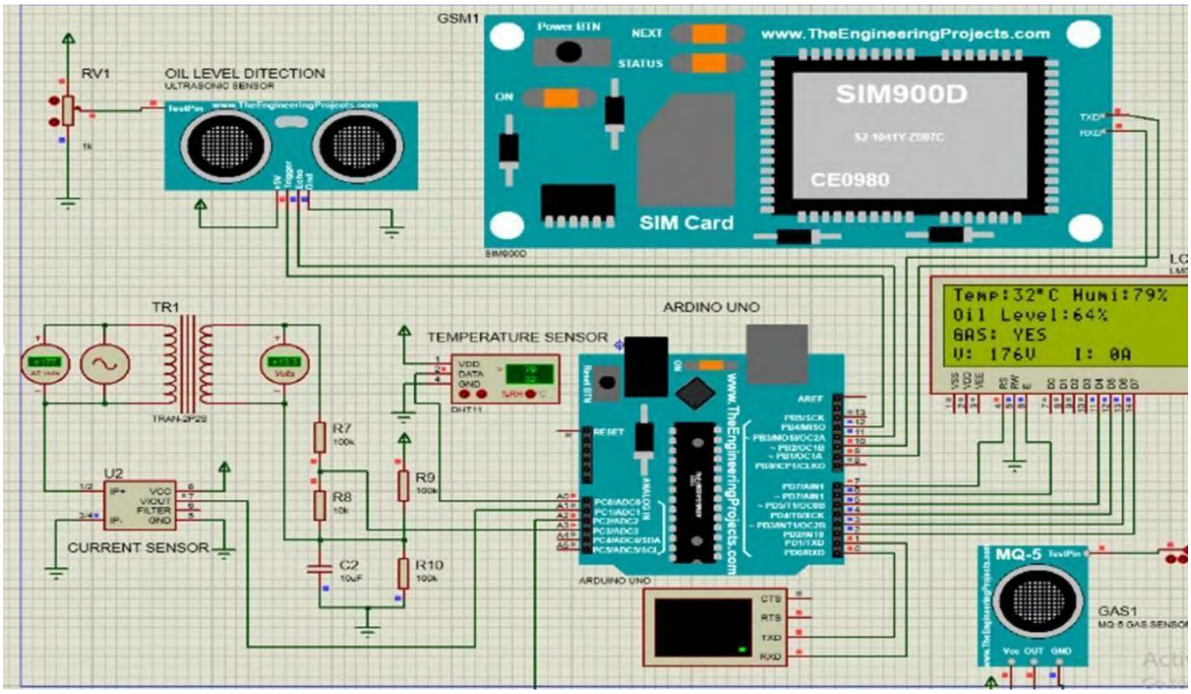

Figure 2.1: Simulated circuit of the Arduino based system

This circuit's power supply component uses a 220V AC mains supply that is stepped down to 12V by an SMPS (Switch Mode Power Supply). After rectification, the output is next sent through a filter to get rid of any remaining AC components. A voltage regulator is used to regulate the voltage to 5V, which powers the remaining components of the circuit. In this project, the main controller is a Node MCU micro controller and an Arduino Nano. Additionally, we employ temperature, gas, ultrasonic, voltage, and current sensors in this application.

The primary objective of our project is to assess the transformer's general health. The project will be able to run when we first begin working on it. We have a sensor installed here. The temperature, voltage, current, and oil condition of the transformer are all tested. If they produce an anomalous circumstance, the system will notify users via an app. The transformer inside oil temperature, transformer current and voltage, and transformer inside oil amount are all measured by temperature, current and voltage, and ultrasonic sensors. With this technology, a flame sensor is further included. If they start a flame, the device will see it and alert them. It serves as the system's primary objective.

The weather temperature and air humidity are measured by temperature sensors, which is crucial for the farming process. The micro controller implements the control circuit. This block diagram shows every component that is necessary for The Design and Implementation of a Power Transformer Monitoring System for the Protection of Transformer Faults. The graphic below shows each component as a separate block. Here, the system is automatically operated by the primary micro controller, an Arduino Pro Mini. This micro controller is connected to other devices, which combine their efforts to produce the desired results.

For oil level detection:

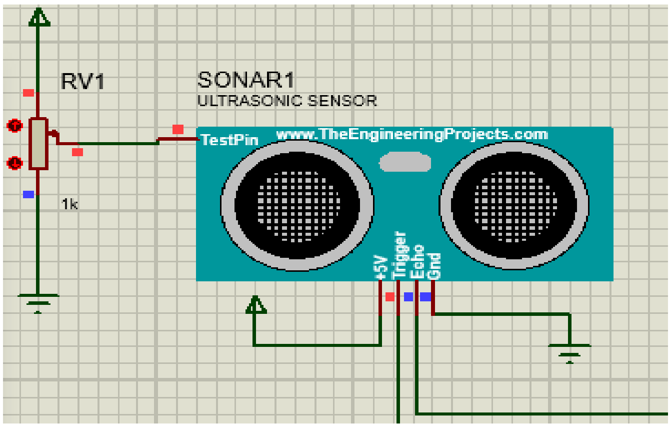

Figure 2.2: We can change values manually in the sensor

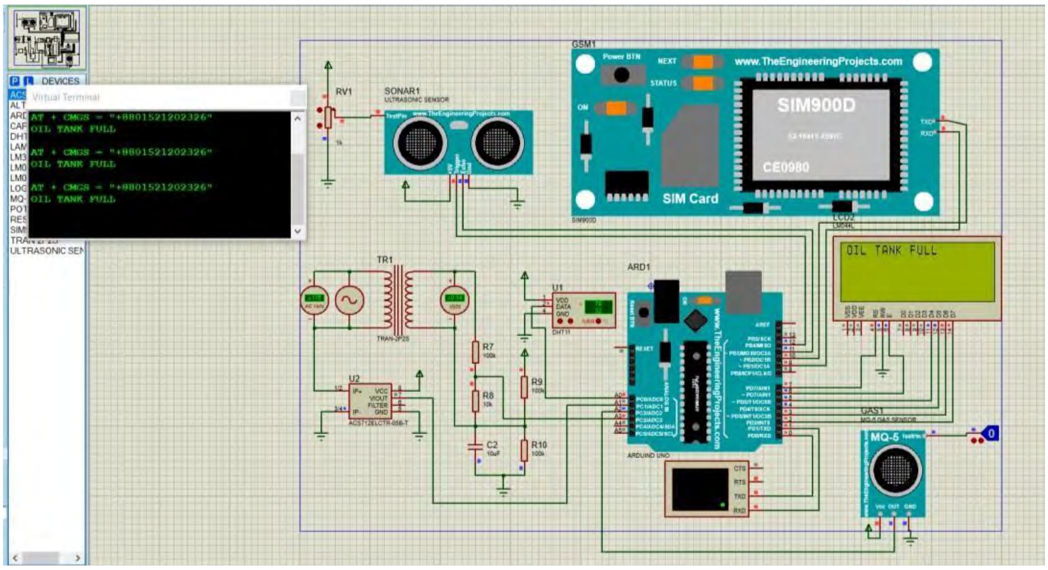

Figure 2.3: For different values the tank is full.

For temperature and humidity detection:

The Sonar R1 Ultrasonic Sensor works in the simulation by emitting a high-frequency sound wave that travels through the air and reflects when it encounters an object. The time taken for the sound wave to travel back and forth between the sensor and the object is measured and used to calculate the distance between the sensor and the object.

In the case of a transformer monitoring system for detecting oil levels, the sensor is placed at the top of the transformer tank, and the distance reading obtained from the sensor is used to calculate the oil level in the tank. As the oil level decreases, the distance between the sensor and the oil surface increases, and vice versa.

To detect if the tank is full or low in the simulation, we set up a threshold value for the distance reading obtained from the sensor. For example, if the distance reading is below the 30-threshold value, the system can indicate that the tank is full, and if the distance reading is 80, the system indicates that the tank is low on oil.

The exact threshold values for full and low levels would depend on the specific application and the characteristics of the sensor used. If the threshold values are set, the system can monitor the distance reading from the sensor and provide an indication of the oil level in the transformer tank based on whether the distance reading falls above or below the threshold values.

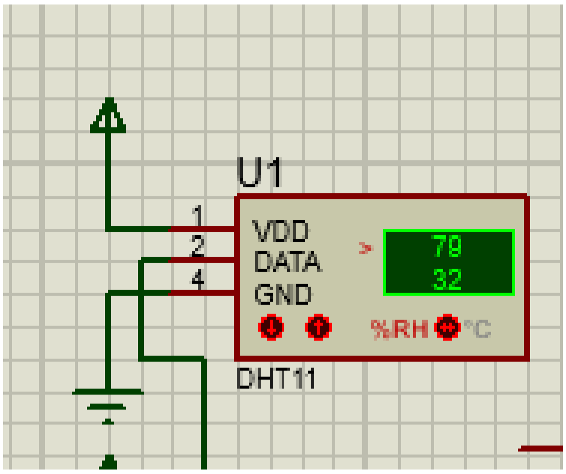

Figure 2.4: DHT11 sensor in the system

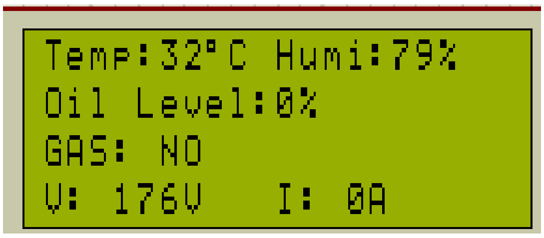

Figure 2.5: Values in the display

The DHT11 sensor is a digital temperature and humidity sensor that can be used with an Arduino-based transformer monitoring system to detect temperature and humidity levels inside a transformer tank. Here is how the sensor works in the simulation and how it detects temperature and humidity levels:

The DHT11 sensor is connected to the Arduino board using digital pins. The sensor is designed to communicate using a single-wire digital protocol, which makes it easy to interface with Arduino boards.

The sensor contains a thermistor and a capacitive humidity sensor that measure temperature and humidity levels, respectively. The thermistor is a type of resistor that changes its resistance with temperature, while the capacitive humidity sensor changes its capacitance with humidity.

To measure the temperature and humidity levels, the Arduino board sends a start signal to the DHT11 sensor. The sensor then responds with a signal containing the temperature and humidity data.

The Arduino board reads the data signal from the DHT11 sensor and converts the data into temperature and humidity values. The data is usually in a binary format that needs to be decoded before it can be used.

Once the temperature and humidity values have been obtained, they can be processed and displayed in the monitoring system. We can set thresholds for the temperature and humidity levels based on the specific requirements of the application. If the temperature or humidity level exceeds the set thresholds, the monitoring system can issue alerts or take appropriate actions for the DTH11 sensor; the range is 0-50 degrees. the maximum rated temperature for a typical power transformer can range from 85°C to 150°C. the IEEE C57.91 standard specifies a temperature limit of 55°C for oil-immersed transformers and a temperature rise limit of 65°C for dry-type transformers. As, in the simulation, we are dealing with less voltage we are using DTH11 which can be used in low-voltage distribution transformers easily.

For Gas detection:

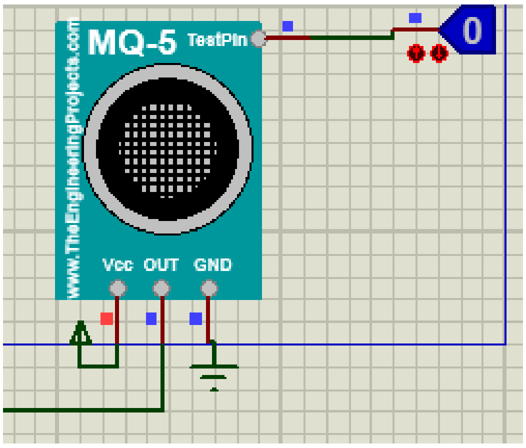

Figure 2.6: Gas Sensor

If the value is 0 then there is no gas in the system but if the value turns 1 the sensor will detect gas and send a signal.

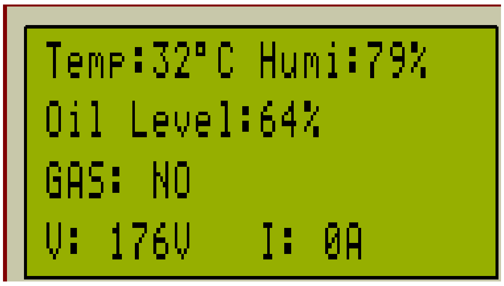

Figure 2.7: Gas Detection on LCD

As the value in the sensor is 0. We can see there is no gas present in the system .

The Arduino board reads the data signal from the DHT11 sensor and converts the data into temperature and humidity values. The data is usually in a binary format that needs to be decoded before it can be used.

Once the temperature and humidity values have been obtained, they can be processed and displayed in the monitoring system. We can set thresholds for the temperature and humidity levels based on the specific requirements of the application. If the temperature or humidity level exceeds the set thresholds, the monitoring system can issue alerts or take appropriate actions for the DTH11 sensor; the range is 0-50 degree. the maximum rated temperature for a typical power transformer can range from 85°C to 150°C. the IEEE C57.91 standard specifies a temperature limit of 55°C for oil-immersed transformers and a temperature rise limit of 65°C for dry-type transformers. As, in the simulation we are dealing with less voltage we are using DTH11 which can be used in low voltage distribution transformers easily.

The MQ-15 gas sensor is a semiconductor-based sensor that can be used in an Arduino-based transformer monitoring system to detect the presence of gases such as nitrogen dioxide, alcohol, benzene, and carbon monoxide. Here is how the sensor works in the simulation and how it detects the presence of gas:

The MQ-15 gas sensor is connected to the Arduino board using analog pins. The sensor is designed to provide an analog output voltage that changes with the concentration of the gas being detected.

The sensor contains a sensing element made of a tin dioxide (SnO_2) semiconductor material. When the gas being detected meets the sensing element, the resistance of the semiconductor changes, which in turn changes the output voltage of the sensor.

To detect the presence of gas, the Arduino board reads the analog output voltage from the MQ-15 sensor and converts it into a gas concentration value. The conversion process involves calibrating the sensor and applying a mathematical formula to the sensor's output voltage.

Once the gas concentration value has been obtained, it can be processed and displayed in the monitoring system. when the gas concentration exceeds the set threshold, the monitoring system can issue alerts or take appropriate actions.

<u>**AI/ Raspberry Pi Based Transformer Monitoring System:**</u>

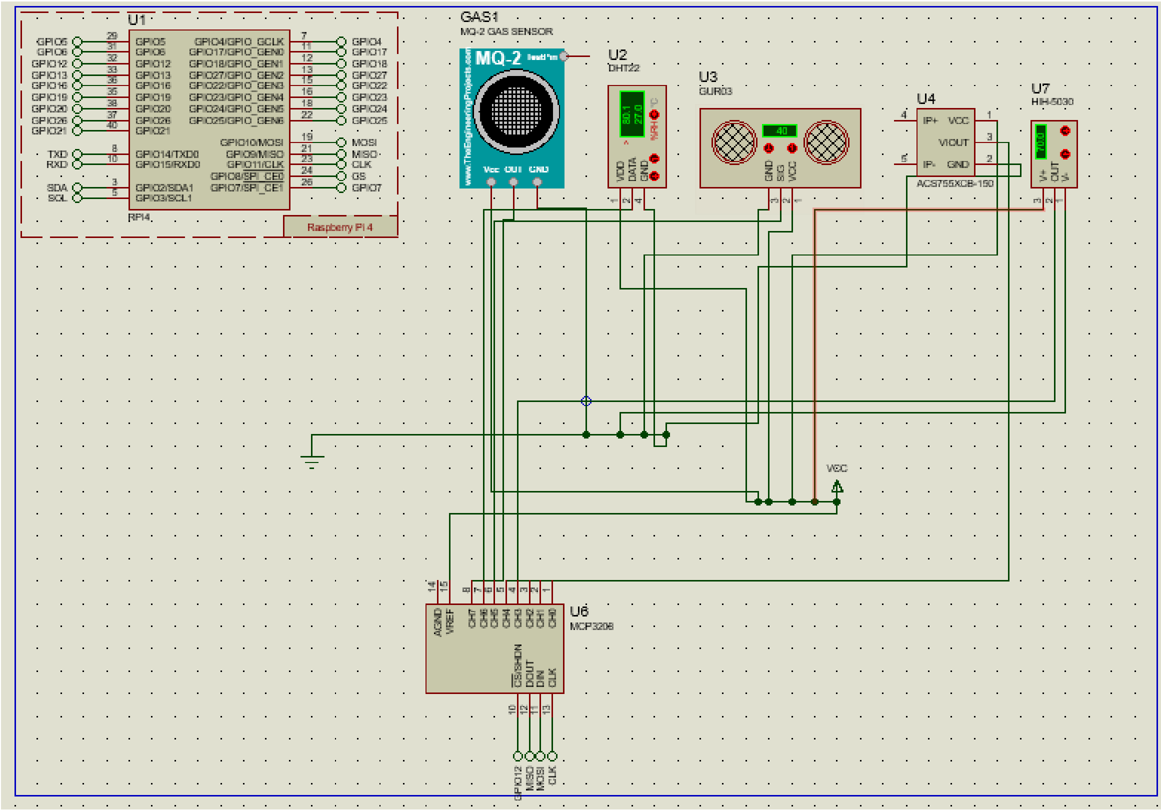

Figure 2.8: Simulated circuit of the AI/Raspberry based system

In this design, we've made the Raspberry Pi, a line of compact single-board computers, the only source of control. The initial focus of the Raspberry Pi project was to encourage the study of fundamental computer science in classrooms and in underdeveloped nations. Its AI (artificial intelligence) is quite powerful. Developing the project in this system will provide much higher output accuracy and have many advantages, but it has one significant drawback: it will be very expensive

MCP3208 connection: communication through SPI interfacing
Channel 04: Voltage Sensor
Channel 05: Ultrasonic Sensor
Channel 06: Current Sensor
Channel 07: DHT22 Temperature Sensor
Channel 08: Gas Sensor

Simulation step:

1. Raspberry Pi has a limited number of analog inputs, but it can use analog-to-digital converters (ADC) to convert analog signals into digital signals that can be read by the Raspberry Pi. To get multiple analog sensor data in Raspberry Pi, one can use an ADC with multiple channels.

2. There are several ADCs available that can be connected to the Raspberry Pi to get multiple analog sensor data. One popular ADC is the MCP3008, which has eight channels and can be connected to the Raspberry Pi using the SPI (Serial Peripheral Interface) protocol.

3. To use the MCP3008 ADC with the Raspberry Pi, one needs to connect the ADC to the Raspberry Pi's SPI pins and then use software libraries such as the "PIGPIO" library or "RPI.GPIO" library to communicate with the ADC and read the analog sensor data. By using an ADC with multiple channels, we can connect multiple analog sensors to the Raspberry Pi and read their data simultaneously.

2.5 Conclusion

To sum up we can say that, while analyzing both the design approaches it was quite evident that the Arduino-based monitoring system had a smooth run.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

In this chapter we have categorized some of the vital engineering tools that will be needed to build the system and run it smoothly.

3.2 Select appropriate engineering and IT tools

IT and engineering tool List:

- ➔ Arduino Pro Mini
- ➔ LCD Display
- ➔ Current Sensor
- ➔ Voltage Sensor
- ➔ Ultrasonic Sensor
- ➔ MQ2 Sensor
- ➔ Temperature Sensor
- ➔ Relay
- ➔ Buck Converter
- ➔ Buzzer
- ➔ 5V Regulator IC

IT tools:

- ➔ Arduino IDE Software
- ➔ Easy EDA Software

3.3 Use of modern engineering and IT tools

Arduino Pro Mini:

The Arduino Pro Mini is a micro controller board based on the ATmega168. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six-pin header can be connected to an FTDI cable to provide USB power and communication to the board. The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P. We used it as the main controller of our project.

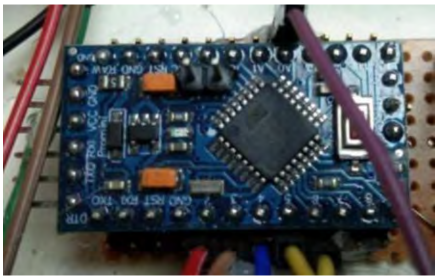

Figure 3.1: Arduino Pro Mini

<u>Pin Out</u>

Each of the 14 digital pins on the Pro Mini can be used as an input or output, using pin Mode (), digital Write (), and digital Read () functions. They operate at 3.3 or 5 volts (depending on the model). Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 K-ohms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the TX-0 and RX-1 pins of the six-pin header.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attached Interrupt () function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analog Write () function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it is off.

The Pro Mini has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). Four of them are on the headers on the edge of the board; two (inputs 4 and 5) on holes in the interior of the board. The analog inputs measure from ground to VCC. Additionally, some pins have specialized functionality:

There is another pin on the board:

- Reset. Bring this line LOW to reset the micro controller. Typically used to add a reset button to shields which block the one on the board.

- GND: Another ground pin.
- A6: Analog input 6.
- A7: Analog input 7.
- A0-A5: Analog input pins A0 through A5.
- 13 (SCK): SPI clock pin.
- 12 (MISO): SPI Master In Slave Out.
- 11 (MOSI): SPI Master Out Slave In.
- 10 (SS): SPI Slave Select.
- 9: PWM (Pulse Width Modulation) pin.
- 8: PWM pin.
- 7: PWM pin.
- 6: PWM pin.
- 5: PWM pin.
- 4: PWM pin.
- 3: Interrupt 1.
- 2: Interrupt 0.
- TXO: Transmit pin of the hardware serial port.
- RXI: Receive pin of the hardware serial port.

Pins labeled as "PWM" support Pulse Width Modulation, allowing for analog output using the analog Write **()** function in the Arduino IDE. Additionally, the Pro Mini does not have an on-board USB-to-Serial converter, so an external converter is typically needed for programming.

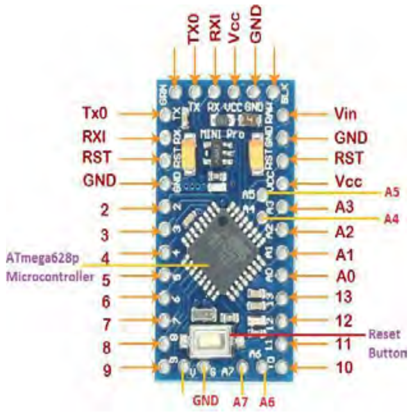

Figure 3.2: Arduino Pro Mini Pin Out

LCD Display:

LCD (liquid crystal display) is an electronic display module and search application. The 16x2 LCD is a very basic module and it is very commonly used in many devices and circuits. These modules are often more than seven sections and many more. All the data is mainly shown on the LCD display.

Figure 3.3: 16*2 LCD Display

The reasons for having an LCD are economical; The characters are easily programmable, special, and even custom (in seven different sections), and there are no restrictions for displaying animations. The 16x2 LCD means that it can display 16 characters per line and contain 2 lines. Each character on this LCD is displayed in a 5x7 pixel matrix.

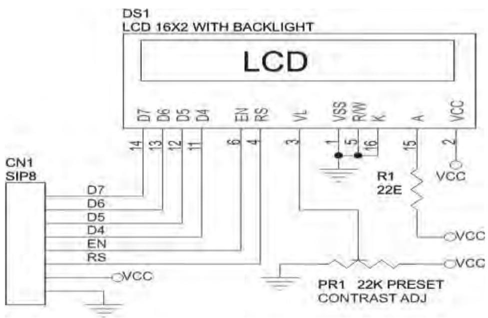

Figure 3.4: 16*2 LCD Display interfacing with Arduino

Current Sensor:

The module is equipped with the ZMCT103C series of small high-precision current transformers and high-precision op-amp circuits for accurate sampling and proper compensation of signals. It is convenient for signal acquisition of AC power within 5A. The corresponding output analog AC signal can be adjusted. The required output voltage can be adjusted according to the potentiometer (adjusting the amplification ratio, the amplification range is 0-100 times), but the maximum voltage at the output (OUT) will not exceed 1/2 VCC

Voltage Sensor:

ZMPT101B AC Single Phase voltage sensor module is based on a high-precision ZMPT101B voltage Transformer. ZMPT101B AC Voltage Sensor is the best for the DIY project, where we need to measure the accurate AC voltage with a voltage transformer. This is an ideal choice to measure the AC voltage using Arduino /ESP8266 /Raspberry Pi like an open-source platform. In many electrical projects, engineers directly deal with measurements with a few basic requirements like High galvanic isolation, Wide Range, High accuracy, and Good Consistency. Onboard precision miniature voltage transformer, The active phase AC output voltage transformer module. Onboard precision op-amp circuit, the signal sampling, and appropriate compensation for precise functions. Modules can be measured within 250V AC voltage, and the corresponding analog output can be adjusted. It is brand new, good quality, and high performance.

Features: -

- Voltage up to 250 volts can be measured
- Lightweight with on-board micro-precision voltage transformer
- High precision on-board op-amp circuit
- Operating temperature: 40ºC ~ + 70ºC
- Supply voltage 5 volts to 30 volts

Advantages:

- Analog output corresponding quantity can be adjusted.
- PCB board size: 49.5 (mm) x19.4 (mm)
- Good consistency, for voltage and power measurement
- Very efficient and accuracy

Ultrasonic Sensor:

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has traveled to and from the target). We mainly used it to measure the oil level in our transformers.

HC-SR04 Ultrasonic Sensor - Working

As shown above, the HC-SR04 Ultrasonic (US) sensor is a 4-pin module, whose pin names are VCC, Trigger, Echo, and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eye-like projects in the front which form the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that

Distance = Speed × Time

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected toward the sensor this reflected wave is observed by the Ultrasonic receiver module.

MQ2 Smoke Detector Module:

The utility model can be used for gas leakage monitoring devices in families and factories, and is suitable for the detection of liquefied petroleum gas, butane, propane, methane, Hydrogen, smoke, etc. This is a very easy to use low-cost semiconductor Gas sensor Module with analog and digital output.

Working Principle:

The MQ-15 gas sensor is connected to the Arduino board using analog pins. The sensor is designed to provide an analog output voltage that changes with the concentration of the gas being detected.

The sensor contains a sensing element made of a tin dioxide (SnO_2) semiconductor material. When the gas being detected meets the sensing element, the resistance of the semiconductor changes, which in turn changes the output voltage of the sensor.

To detect the presence of gas, the Arduino board reads the analog output voltage from the MQ-15 sensor and converts it into a gas concentration value. The conversion process involves calibrating the sensor and applying a mathematical formula to the sensor's output voltage.

Once the gas concentration value has been obtained, it can be processed and displayed in the monitoring system. when the gas concentration exceeds the set threshold, the monitoring system can issue alerts or take appropriate actions.

Temperature Sensor:

The DHT11 sensor is a digital temperature and humidity sensor that can be used with an Arduino-based transformer monitoring system to detect temperature and humidity levels inside a transformer tank. Here is how the sensor works in the simulation and how it detects temperature and humidity levels:

The DHT11 sensor is connected to the Arduino board using digital pins. The sensor is designed to communicate using a single-wire digital protocol, which makes it easy to interface with Arduino boards.

The sensor contains a thermistor and a capacitive humidity sensor that measure temperature and humidity levels, respectively. The thermistor is a type of resistor that changes its resistance with temperature, while the captive humidity sensor changes its capacitance with humidity.

To measure the temperature and humidity levels, the Arduino board sends a start signal to the DHT11 sensor. The sensor then responds with a signal containing the temperature and humidity data.

The Arduino board reads the data signal from the DHT11 sensor and converts the data into temperature and humidity values. The data is usually in a binary format that needs to be decoded before it can be used. Once the temperature and humidity values have been obtained, they can be processed and displayed in the monitoring system. We can set thresholds for the temperature and humidity levels based on the specific requirements of the application. If the temperature or humidity level exceeds the set thresholds, the monitoring system can issue alerts or take appropriate actions for the DTH11 sensor; the range is 0-50 degree. the maximum rated temperature for a typical power transformer can range from 85°C to 150°C. the IEEE C57.91 standard specifies a temperature limit of 55°C for oil-immersed transformers and a temperature rise limit of 65°C for dry-type transformers. As in the simulation, we are dealing with less voltage we are using DTH11 which can be used in low-voltage distribution transformers easily.

Relay:

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

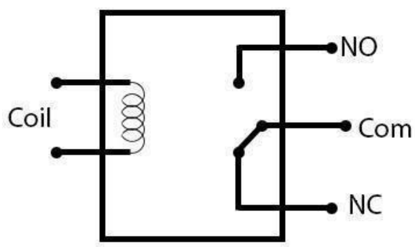

Figure 3.5: Relay

Buck Converter:

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while drawing less average current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). It is called a buck converter because the voltage across the induct or "bucks" or opposes the supply voltage.

Buzzer:

There are many ways to communicate between the user and a product. One of the best ways is audio communication using a buzzer IC. So, during the design process, understanding some technologies with configurations is very helpful. So, this article discusses an overview of an audio signaling device like a beeper or a buzzer and its working with applications .An audio signaling device like a beeper or buzzer may be electromagnetically or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound.

Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarms, music, bell & sirens. The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the „+‟ symbol or a longer terminal. This terminal is powered through 6 Volts whereas the negative terminal is represented with the „-„ symbol or short terminal and it is connected to the GND terminal.

Buzzer Circuit Diagram

The circuit diagram of the water level indicator using the buzzer is shown below. This circuit is used to sense or detect the water level within the tank or washing machine or pool, etc. This circuit is very simple to design using few components such as a transistor, buzzer, 300K variable resistor, and power supply or 9V battery.

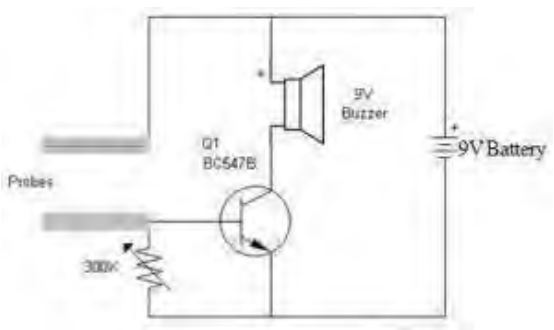

Figure 3.6: Water Level Circuit using Buzzer

Once the two probes of the circuit are placed in the tank, it detects the level of water. Once the water level exceeds the fixed level, then it generates a beep sound through a buzzer connected to the circuit. This circuit uses a BC547B NPN transistor however we can also use any general-purpose transistor instead of using 2N3904/2N2222.

This water level sensor circuit working is very simple and the transistor used within the circuit works as a switch. Once the two probes notice the water level within the tank, then the transistor turns ON & the voltage begins flowing throughout the transistor to trigger the buzzer.

5V Regulator IC:

Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 IC, a member of 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC). The xx in 78xx indicates the output voltage it provides. 7805 IC provides +5 volts regulated power supply with provisions to add a heat sink.

7805 IC Rating

- Input voltage range 7V- 35V
- Current rating IC = 1A
- Output voltage range V-Max=5.2V, V-Min=4.8V

Arduino IDE:

The digital micro controller unit named as Arduino Nano can be programmed with the Arduino software IDE. There is no requirement for installing other software rather than Arduino. Firstly, Select "Arduino Nano from the Tools, Board menu (according to the micro controller on our board). The IC used named as ATmega328 on the Arduino Nano comes pre-burnt with a boot loader that allows us to upload new code to it without the use of an external hardware programmer. Communication is using the original STK500 protocol (reference, C header files). We can also bypass the boot loader and program the micro controller through the ICSP (In Circuit Serial Programming) header. The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode. The Arduino Nano is one of the latest digital micro controller units and has a few facilities for communicating with a computer, another Arduino, or other micro controllers. The ATmega328 provides UART TTL at (5V) with serial communication, which is available on digital pins 0 -(RX) for receiving the data and pin no.1 (TX) for transmitting the data. An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .in file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board.

The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial Communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Nano's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication.

EASYEDA Software:

EASYEDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share - publicly and privately - and discuss schematics, simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. EASYEDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

Subscription-free membership is offered for the public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge; but for a fee, EASYEDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third-party tools.

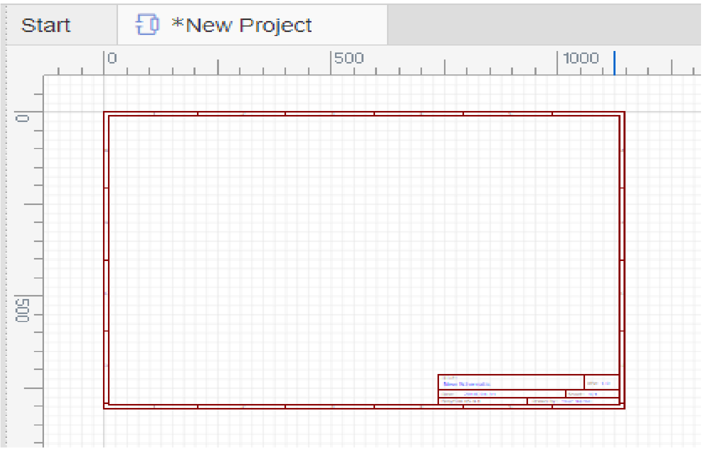

Figure 3.7: EASYEDA Software Interface

3.4 Conclusion

The "design and implementation of an automated transformer monitoring system" project represents a significant advancement in modern engineering and IT tools applied to the power distribution sector. By combining sensors, micro controllers, wireless communication, and data analysis, the system provides real-time monitoring, early fault detection, and proactive maintenance for power transformers. This innovative approach ensures the reliable operation of electrical power systems, minimizes downtime and contributes to grid stability and cost savings. As the demand for efficient and intelligent power systems continues to grow, this project sets a remarkable example of leveraging technology for the protection of critical infrastructure. One of the key strengths of EASYEDA lies in its cloud-based collaborative capabilities, allowing users to seamlessly work on projects in real-time, fostering teamwork and innovation. The software's integration of schematic capture, PCB layout, and simulation functionalities within a single platform streamlines the design process, eliminating the need for multiple software tools and ensuring a more coherent and synchronized workflow. The flexibility and versatility of EASYEDA are commendable, enabling users to design and simulate circuits for various applications, from simple hobbyist projects to complex professional endeavors. The extensive component library and the option to import custom components contribute to the software's adaptability to diverse design requirements. Additionally, the affordability of EASYEDA, particularly in comparison to some traditional design tools, makes it an attractive choice for budget-conscious individuals and small businesses. The continuous updates and improvements by the development team further enhance the software's performance and keep it aligned with industry standards. In essence, EASYEDA stands out as a commendable solution for electronic design and simulation, offering a blend of accessibility, functionality, and collaboration. Its user-friendly nature, coupled with a rich feature set, positions EASYEDA as a compelling choice for individuals and teams seeking an efficient and cost-effective electronic design solution. As technology advances, it will be intriguing to witness how EASYEDA continues to evolve and maintain its relevance in the dynamic landscape of electronic design.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

To determine the optimal solution of the project, some important measures should be taken. Our project has two approaches and to find out the better one, we have to analyze both. After doing software simulation for both designs and sufficient research, we compared the results. Then, we concluded to choose the right one that will satisfy our requirements.

4.2 Optimization of multiple Design

Table 4.1: Comparison between Arduino and AI

Basis	Arduino	AI
Accuracy	Low observation accuracy	Precise observation
Problematic Characteristics	Can sometimes hang and not respond.	Can sometimes hang and not respond.
Working Duration	Prolonged use may cause problems	A system restart may be required after prolonged use.
Compatibility	Limited Compatibility with third party software and hardware.	More Compatibility with third party software and hardware.
Technical Complexity	Medium	Very High
Control	Hard	Very Hard
Sustainability	Medium	High
User Comfort ability and Level of Interaction	High Lower	Low Lowest
Cost -Effectiveness Analysis	Low-cost hardware and software that is appropriate for students and hobbyists	Higher-priced hardware and software suitable for businesses and professionals
Ease of Usage	With a large community of users and resources, it is simple to set up and program.	Setup and programming require more technical knowledge and experience, but it offers more advanced features and functionalities.
Software Capabilities	Basic programming language with a simple development environment but limited data processing and analysis capabilities.	Multiple programming languages with advanced development environments, libraries, and frameworks for data processing, analysis, and visualization

Hardware Capabilities	Limited storage, memory, and processing power, but supports a range of sensors and modules.	Wi-Fi, Bluetooth, and Ethernet connectivity with strong processing, memory, and storage capabilities; may need additional sensors and modules.
Programming Language	C/C+	Multiple (Java, Python etc)

Here our first model is Arduino Nano based. This system is useful for very small expansions. All of these are usually used first for preparatory work. This is the best for basic work. Here the system works as the code is uploaded to the micro controller by programming. If this system is made with a micro controller, it will be very small and will work beautifully with a transformer. The second model we discussed was the AI Controller. This technology is also very expensive. This technology can be used in industrial work. It gives very accurate results.

4.3 Identify optimal design approach

For design approach 1, the parts that are used can be easily found in the local markets. Such as the sensors, switch, load, Arduino nano etc. but for design approach 2, the Raspberry pi can be hard to implement and the analog input options are limited.

Arduino can be easily implemented and does not require intense knowledge of programming language. It can use the software IDE for coding which is open source.
Also design 1 is more cost effective and consumes less energy than design 1.

4.4 Performance Evaluation of Developed Solution

After thorough analysis we have come to a decision that design 1 is the best solution for the transformer monitoring system than design 2. By implementing the project and test run a few times it worked according to our requirements.

- In our project we have used a 220 V transformer, some sensors, buck converter, relay, switchboard, buzzer, LCD display and load. We have to set a range of values for the sensors. So, for the voltage sensor we have set a range which is 190V-240V. Values less than 190V and higher than 240V makes the buzzer activate and the load gets turned off. The LCD display shows „over voltage‟, ‟under voltage‟. Same for the other sensors. For the oil level sensor, the limit is <3 cm, lower than that shows „oil level is low‟. For the temperature sensor $>37^0$C, „Temperature is high‟ shown in the display and if any type of gas is detected the display shows „Gas detected‟.
- Our goal was to build a system that can detect any faults beforehand and notify us automatically, which is being established by this design 1.

4.5 Conclusion

To conclude, we can see that both the designs have some pros and cons of their usage. But after exploration and a few trials we chose the optimal solution. The system has done quite well and the result is quite satisfactory. But it has some future upgrading scopes using modern tools. Overall, the system can work automatically and independently.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

In this chapter, we will discuss the final stages of the project, focusing on the completion of the final design and the validation of the solution. After all the planning and implementation phases, it is crucial to ensure that the system meets the desired needs and functions effectively.

5.2 Completion of final design

In this part we show our project circuit design and connect out instrument through standard wire.

- ➢ Data Collection: Sensors continuously monitor various parameters such as temperature, oil level, voltage, and current in real-time.
- ➢ Data Processing: The micro controller receives data from sensors and processes it, comparing the values to predefined thresholds and patterns.
- ➢ Fault Detection: If any anomalies or faults are detected, the system triggers alerts and notifications to the central monitoring station and operators.
- ➢ Communication: Data, alerts, and notifications are transmitted via wireless communication technologies (e.g., GSM or Wi-Fi) to the central monitoring station, enabling remote monitoring.
- ➢ User Interaction: Operators can access the system through a user interface (e.g., mobile app or web interface) to view real-time data, receive alerts, and make informed decisions.
- ➢ Maintenance: Maintenance personnel can proactively address potential issues based on real-time data and predictive maintenance analysis.

Final Project Image:

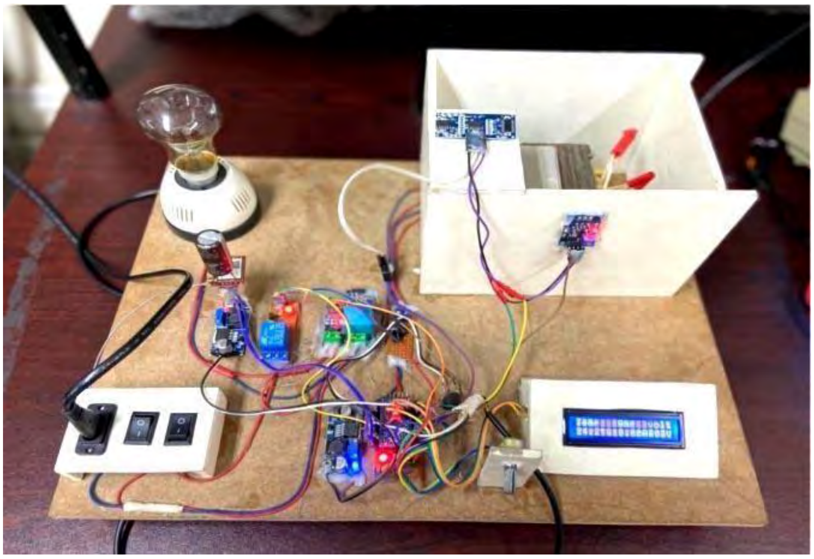

Figure 5.1: Final prototype

Working Procedure

In the circuit's power supply section, a 220V AC from the mains supply is stepped down to 12V via a rectifier circuit. After rectification, the output is next fed through a filter to get rid of any remaining AC components. A voltage regulator is used to regulate the voltage to 5V, which powers the remaining components of the circuit. A micro-controller called an Arduino Pro Mini serve as the primary controller in this project. We also use temperature sensors, gas sensors, ultrasonic sensors, voltage sensors, current sensors, relays, buck converters, LCD displays, and more in this application. Our project's primary goal is to assess the transformer's general health. The project will be able to function when we first begin working on it. We have a sensor attached here. The temperature, voltage, current, and oil condition of the transformer are all tested. Transformer internal oil temperature is measured via a temperature sensor. Transformer current and voltage parts are measured by current and voltage sensors, and transformer internal oil volume is measured by ultrasonic sensors. With this device, a smoke sensor is additionally installed. It serves as the system's primary objective.

5.3 Evaluate the solution to meet desired need

Voltage and Current Measurement:

- The normal voltage range is 190V-240V.
- If voltage < normal level LCD display will show 'under voltage' and if it's higher „Over Voltage'
- But if it's within range the load/light will stay ON.
- In both under and over voltage situations a buzzer will be On.

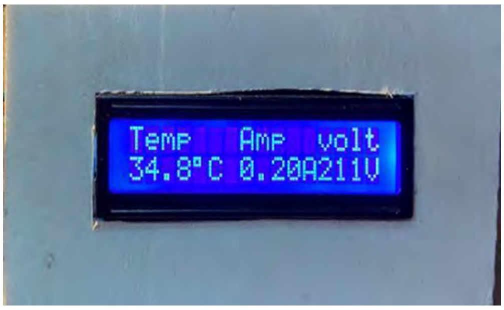

Figure 5.2: Normal voltage

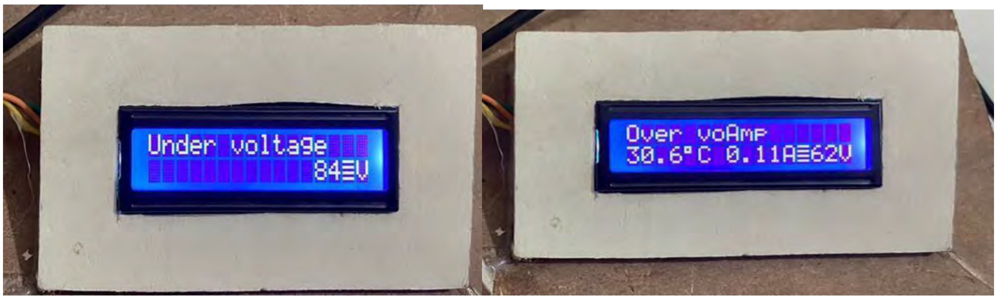

Figure 5.3: For under and over voltage

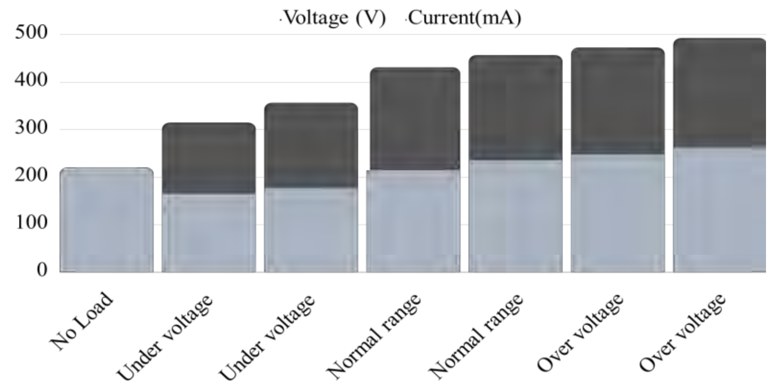

Figure 5.4: Different voltage level

Oil Level detection:

The Sonar R1 Ultrasonic Sensor works in the simulation by emitting a high-frequency sound wave that travels through the air and reflects back when it encounters an object. The time taken for the sound wave to travel back and forth between the sensor and the object is measured and used to calculate the distance between the sensor and the object.

In the case of a transformer monitoring system for detecting oil level, the sensor is placed at the top of the transformer tank, and the distance reading obtained from the sensor is used to calculate the oil level in the tank. As the oil level decreases, the distance between the sensor and the oil surface increases, and vice versa.

To detect if the tank is full or low in the simulation, we set up a threshold value for the distance reading obtained from the sensor. For example, if the distance reading is below 30 threshold value, the system can indicate that the tank is full, and if the distance reading is 80, the system indicates that the tank is low on oil.

The exact threshold values for full and low levels would depend on the specific application and the characteristics of the sensor used. O the threshold values are set, the system can monitor the distance reading from the sensor and provide an indication of the oil level in the transformer tank based on whether the distance reading falls above or below the threshold values.

- Ultrasonic sensor detects the oil level
- Oil Level < 3 cm is considered low
- In the Fig, we see the message "Oil level low". The oil level we measured was less than 3cm that's why the display is showing the result with a buzzer.

Figure 5.5: When oil level goes under 3 cm

Temperature detection:

The DHT11 sensor is a digital temperature and humidity sensor that can be used with an Arduino-based transformer monitoring system to detect temperature and humidity levels inside a transformer tank. Here's how the sensor works in the simulation and how it detects temperature and humidity levels:

The DHT11 sensor is connected to the Arduino board using digital pins. The sensor is designed to communicate using a single-wire digital protocol, which makes it easy to interface with Arduino boards.

The sensor contains a thermistor and a capacitive humidity sensor that measure temperature and humidity levels, respectively. The thermistor is a type of resistor that changes its resistance with temperature, while the capacitive humidity sensor changes its capacitance with humidity.

To measure the temperature and humidity levels, the Arduino board sends a start signal to the DHT11 sensor. The sensor then responds with a signal containing the temperature and humidity data.

The Arduino board reads the data signal from the DHT11 sensor and converts the data into temperature and humidity values. The data is usually in a binary format that needs to be decoded before it can be used.

Once the temperature and humidity values have been obtained, they can be processed and displayed in the monitoring system. We can set thresholds for the temperature and humidity levels based on the specific requirements of the application. If the temperature or humidity level exceeds the set thresholds, the monitoring system can issue alerts or take appropriate actions for the DTH11 sensor; the range is 0-50 degree. The maximum rated temperature for a typical power transformer can range from 85°C to 150°C. The IEEE C57.91 standard specifies a temperature limit of 55°C for oil-immersed transformers and a temperature rise limit of 65°C for dry-type transformers. As, in the simulation we are dealing with less voltage we are using DTH11 which can be used in low voltage distribution transformers easily .

- The temperature is 44.5ºC and 38.4ºC.
- The display shows "Temperature high" in the case because above 37ºC is considered overheating.
- The buzzer will be 'ON'. When it gets below 37ºC then it will be normal**.**

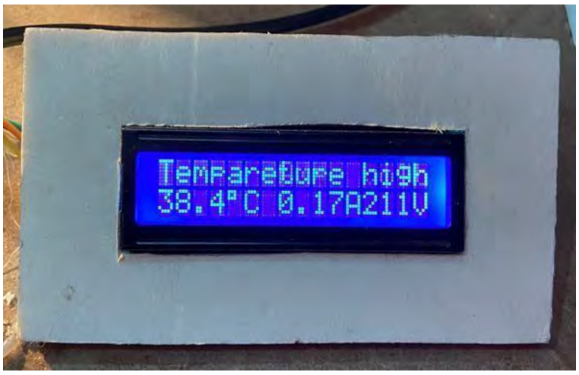

Figure 5.6: High temperature Alert

Gas detection:

The gas sensor is a semiconductor-based sensor that can be used in an Arduino-based transformer monitoring system to detect the presence of gasses such as nitrogen dioxide, alcohol, benzene, and carbon monoxide. Here's how the sensor works in the simulation and how it detects the presence of gas:

The gas sensor is connected to the Arduino board using analog pins. The sensor is designed to provide an analog output voltage that changes with the concentration of the gas being detected.

The sensor contains a sensing element made of a tin dioxide (SnO2) semiconductor material. When the gas being detected encounters the sensing element, the resistance of the semiconductor changes, which in turn changes the output voltage of the sensor.

To detect the presence of gas, the Arduino board reads the analog output voltage from the MQ-15 sensor and converts it into a gas concentration value. The conversion process involves calibrating the sensor and applying a mathematical formula to the sensor's output voltage.

Once the gas concentration value has been obtained, it can be processed and displayed in the monitoring system. when the gas concentration exceeds the set threshold, the monitoring system can issue alerts or take appropriate actions.

The gas sensor will detect any gas emitting from the oil and show "gas detected' on the display as shown in the picture.

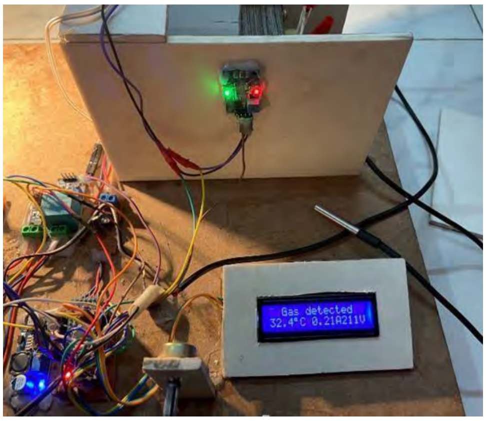

Figure 5.7: Gas detection

5.4 Conclusion

The completion of the final design and validation phase is a critical milestone in the project. It ensures that the developed power transformer monitoring system is not only technically sound but also meets the practical needs of users. By thoroughly evaluating the solution, addressing any shortcomings, and incorporating user feedback, the project can conclude with confidence that the system is ready for deployment and will contribute significantly to the protection of transformer faults and the reliability of the power distribution system.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

Transformer is a crucial part of the electrical power system which should not be overlooked. Whenever any fault occurs in the system, it creates a negative impact. As an overpopulated country, our need for electricity is high and almost everything needs power to run. But if the transformer gets damaged it causes load-shedding which can last a very long time. In these situations, our project can be a suitable solution.

6.2 Assess the Impact of Solution

As our project is to monitor transformer health automatically, it will be helpful in cases of internal faults. So, it will have a significant impact on the power system. There will be less power cuts and other effective circumstances which are listed below:

6.2.1 Environmental impact

Insulating oil, which is a common component of transformers, can occasionally fail and leak or even catch fire, posing a threat to the environment. By using the system which will let us know if the oil level is within the limited range and take precaution [15].

By preventing electrical faults and failures that could cause power outages, which could have a detrimental impact on the environment, the transformer protection system may also indirectly affect the environment. An interruption in essential services like hospitals, water treatment plants, and transportation networks, for instance, could have a significant effect on public health and safety.

6.2.2 Economic impact

By using a transformer protection system, the system will allow us to know the internal conditions of the transformer. Systems for protecting transformers are crucial for guaranteeing the steady operation of power systems. A transformer is a crucial part of the electrical system, and its failure or damage can have a big influence on the economy. A transformer protection system's main purpose is to swiftly isolate a malfunctioning transformer from the rest of the system in order to limit additional damage. This reduces the amount of downtime and repair expenses brought on by transformer breakdowns [15].

Transformer protection systems can also increase the power system's overall efficiency by lowering the amount of needless maintenance tasks and downtime caused by erroneous alarms or non-fault conditions.

6.2.3 Societal and cultural context

Our project has enormous potential to further change the agriculture industry. Change can be seen in social and cultural contexts. Like-

- Since now all our systems are being modernized, due to our system implementation, there will be a lot of socio-economic development in the country.
- Since substation transformers can be monitored from a specific platform from a remote location, people's time will be saved and they can use their time elsewhere and contribute to the development of the country's economy.
- Due to continuous monitoring, no harmful gas emissions can be emitted and transformer blast or any accident can be avoided so it will not affect the normal life of the society and people.

6.3 Evaluate the sustainability

While planning a project we should be aware of sustainability which is basically an approach that balances the environmental, social, and economic aspects of project-based work to meet present needs without harming future generations.

Table 5: SWOT analysis for the project

	Positive	**Negative**
	Strength	***Weakness***
Internal	● Developed with smart technology. ● Large Scope of monitoring and controlling. ● Good Communication capability. ● More accurate prediction. ● Automatic transformer health monitoring. ● Automatic Over and Low voltage controlling system.	● Initially expensive. ● Hard to control ● Not water-resistant. ● Apps/cloud server development cost.
	Opportunities	*Threats*
External	● This kind of technology is very new in our country so it can attract the attention of the government in the budget and through smart system implementation we can focus on building digital Bangladesh.	The prototype can face cyber attacks. Need more time and security to get used to it.

We can observe from the tabular swot analysis that the strengths and opportunities outweigh the weaknesses and threats.

We are employing modern technologies to develop and maintain this prototype, which will be as relevant as it is now in the near future. This prototype will have features like temperature monitoring, over voltage detection, oil level monitoring and automated cut off system. It will reduce the use of unnecessary power & reduce unforeseen accidents. This prototype can bring balance to the ecosystem as well as prevent environmental pollution. In this way, it can bring environmental sustainability. Over voltage, under voltage can be detected by sensor .We also observed that it is economically sustainable after doing a theoretical analysis of the cost- benefit and reliability. A design of circuit for transformer monitoring. If the transformer is in an abnormal condition we can know from anywhere. No human power needed to monitor the transformer. Details about the transformer are automatically updated in the web page and notified when the transformer is in abnormal condition. We have described a remote monitoring system for distribution transformers utilizing the existing IoT, which has low investment and operation costs. Therefore, we can say Our project is sustainable.

6.4 Conclusion

The extent to which a project is sustainable is a factor in determining its effectiveness. We kept this in mind while doing the design and implementation if it's consistent with the ongoing digitalization of our country in every sector. Otherwise, it will not be valued. Similarly, we carefully examined our project to determine our project's sustainability. Our project is sustainable on a social level. As it can save both our time and money.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1. Introduction

A methodical technique to organize, carry out, oversee, and manage engineering projects from conception to completion is known as engineering project management. It entails adapting project management approaches and principles to the special difficulties and intricacies of engineering projects, which frequently involve developing, building, or enhancing tangible systems, infrastructure, and goods. The timely, economical, and functional completion of engineering projects is guaranteed by effective project management.

7.2 Define plan and Manage Engineering project

There are major key elements of Engineering project management such Definition and Launch of the Project, Project Planning, Resource Management, Quality Management, Cost Management, Schedule Management, Risk Management, Communication and Stakeholder Management, Change Management, Monitoring and Control lastly closure and Evaluation.

Definition and Launch of the Project:

- We all project mates clearly stated our project goals, scope and objectives.
- After that we determined the needs and expectations of the stakeholders.
- Our members reviewed the project's viability, taking technical, monetary, and legal factors into account.
- We Created a project charter or an initiation document to formally authorize the project.

Project Planning:

- Firstly, we made a thorough project plan that includes a list of the tasks, deadlines, milestones, and resources needed.
- Our group leader divided the job into manageable parts and used a work breakdown structure (WBS).
- We Created a risk management strategy by identifying the hazards.
- Then we Created a communication strategy to inform stakeholders.

Resource Management: We Organized and managed resources, such as workers, tools, and supplies. Additionally, make sure that each team member has the knowledge and experience needed to carry out their tasks well. Optimize resource usage as well to reduce expenses and delays.

Quality Management: Then we defined the project's quality requirements and goals. Implement quality control and assurance procedures as well to meet these requirements. Then, to guarantee that the project is meeting the standards for quality, monitor and measure its performance.

Cost Management: Our mates Created a project budget that contains projections for all project expenses. We Keep an eye on and rein in project costs to keep inside on budget. Also Put in place cost-tracking procedures to find and address expense overruns.

Schedule Management: We Created a project schedule that takes critical pathways and task dependencies into account. Additionally, keep track of progress in relation to the timeline and make necessary adjustments to guarantee timely completion and also quickly address schedule concerns and delays.

Communication and Stakeholder Management: For project updates, it is vital to establish efficient communication channels and procedures. Additionally, adequate stakeholder engagement is necessary to manage expectations and address concerns. Should maintain constructive stakeholder connections and settle disputes.

7.3 Project Progression

In our project basically, we tried to monitor the transformer's internal fault by using several types of components for demonstration. We also had three design approaches for our project and finally, we worked with one final design approach. We categorized our project into three different time phases.

PHASE I: This is the starting phase of our project which deals with a project proposal. We selected our topic after that we authorized it from our ATC panel. They gave us brief ideas about our project topic and how we should implement our project according to complex engineering methodology.

Firstly, we selected various types of component requirements for our project. Such as Potential Transformer, Microcontroller, Current Transformer, Temperature sensor, Relay, GSM module, LCD display, Gas sensor, Rectifier filter, Load, Bug converter, and Ultrasonic sensor. After that, we specified our components specification according to our project prototype measurement. In our project, we had some constraints of our project that we needed to focus on. Some of the constraints are extra investment is required, loss of network leads to complete failure and lastly, permission issues are also related there from the local community as we must work physically in a locality where transformers exist. Power transformers are key components for electrical energy transfer in a Power system. To protect the transformers from these faults different protective methods are adopted.

Design approaches: As mentioned earlier we have discussed three design approaches finally we have selected two design approaches for our project implementation. Here are the design approaches: -

1. <u>Arduino Microcontroller Based Transformer Monitoring System</u>

For this design approach, we will see a microcontroller-based Relay protection system that consists of both hardware and software. The relaying function requires a percentage differential protection with the di/dt restraint for inrush current condition over current protection to protect the transformer from overload and external faults, over-voltage, and under-voltage protection. Two types of sensors will be used, oil level sensor and temperature sensor. We will use GSM to send the messages to mobile in case of component failure. LCD will be connected to the microcontroller to display the received message.

2. AI/ Raspberry Pi Based Transformer Monitoring System

This work presents an alternative approach using the differential logic associated with artificial neural networks (ANNs) to distinguish between inrush currents and internal faults for the protection of power transformers. The radial basis function (RBF) neural network is proposed as an alternative approach to distinguish the situations described, using a smaller amount of data for training purposes, in some cases, if compared with networks such as the multi-layer perceptron (MLP). The ANN results are then compared to those obtained by the traditional differential protection algorithm. An ANN approach for the correction of saturated current signals is also presented.

PHASE II: In this phase of our project, we worked on the software part of this project. Where we had to deal with the simulation and coding part. We have worked on two selected design approaches for our project. Here we categorized our requirements into two different parts one is functional another one is non-functional.

The functional parts are data processing, real-time monitoring, remote access, alarms and notifications, data analysis, and reporting. Also, the non-functional parts are reliability, security, scalability, user-friendliness, maintenance, and Interoperability.

Finally, we came up with two design approaches for design and simulation which were

- **Arduino Microcontroller-Based Transformer Monitoring System**

The reason behind choosing this design approach had several features:

- ❖ Has both hardware and software implementation
- ❖ Microcontroller based relay, and A/D converter to process digital data
- ❖ Differential percentage, over and under voltage, over current, oil level, and temperature detection.
- ❖ Use of GSM module to show the changes and store them in a cloud server to access later

For simulation purposes, we used proteus simulation software where we designed our project components. There we faced a little bit of a challenge for selecting specific component names in the software for simulation purposes. There are thousands of components in this software that are very much similar in their specifications.

- **AI/ Raspberry Pi Based Transformer Monitoring System**

  Artificial neural networks (ANNs) or AI in general can be used to create and test protection systems using a variety of simulation software tools and platforms. Power systems, industrial automation, and other fields where the importance of protection systems is paramount frequently use these instruments. We used MATLAB Simulink software to establish its simulation and coding parts. For creating and simulating neural networks and AI algorithms, many programmers utilize MATLAB. Simulink, a MATLAB plugin, is especially helpful for modeling power systems and control systems, making it appropriate for simulations of protection systems using ANNs. This programming platform is completely C-programming language-based.

PHASE III:

Hardware implementation: In this final phase of our Project, we worked on the main hardware part of our project. We have selected our final design approach for implementing our project based on it. That is an Arduino Microcontroller-Based Transformer Monitoring System. Where we implemented and installed all hardware tools of our Project. We had to buy different types of sensors as mentioned earlier. Though it is a prototype that's why we did not have to invest a lot in this project. It is approximately 14 to 16 thousand takas. As we said we need funding for our project to implement this at its field level. For example, the distribution part of the Power system of our country.

Procurement and Equipment Acquisition:

- ➢ Here we Identify and procure the necessary sensors, monitoring equipment, and software.
- ➢ Also, we ensured that all equipment meets the project specifications.
- ➢ Then Established supplier contracts and agreements.

Installation and Infrastructure Setup:

- ➢ Prepared the physical infrastructure for sensor installation.
- ➢ Installed sensors on the transformers and connected them to the monitoring system.
- ➢ Configured the monitoring software and hardware.
- ➢ Conducted initial testing to ensure data is being collected accurately.

Testing and Validation:

- ➢ Performed comprehensive testing of the monitoring system to identify and resolve any issues.
- ➢ Validated the system's performance against the defined requirements.
- ➢ Conducted field tests to ensure the system works in real-world conditions.

Monitoring and Maintenance:

- ➢ Established ongoing monitoring and maintenance procedures.
- ➢ Implemented a regular maintenance schedule to calibrate sensors and update software.
- ➢ Monitored the system data and alerts to proactively address potential transformer faults.

7.4 Conclusion

The complexity, scale, resources available, and potential difficulties of the project will all have an impact on its progress. It's crucial to frequently monitor and report on project progress, to revise budgets and schedules as necessary, and to make sure that stakeholders are effectively communicating at all times.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

A project's economic analysis is a methodical procedure for assessing the viability, costs, and advantages of a particular project or investment opportunity. The main goal of economic analysis is to assess a project's economic viability and to give decision-makers the knowledge they need to choose wisely how to allocate resources to the project. It is an essential technique for determining whether projects are financially feasible and for ensuring that resources are deployed effectively to maximize economic benefits is economic analysis. It aids organizations in making well-informed choices on project investment and project prioritization within budgetary constraints.

Numerous economic and cost-benefit assessments are conducted as part of this project to determine its viability and potential return on investment.

8.2 Economic Analysis

Table 6.1: Cost Analysis

Objects	Components	Quantity	price (BDT)
Controller	Arduino Node MCU	1	3500
	Micro SD card	1	1400
Power supply	Power Source	1	3200
Output	Relay Module	1	1500
	LCD Display	1	800
	Transformer	1	350
	Other PVC board, PCB, Lead etc.	1	1250
Sensor	Voltage Sensor	1	1200
	Ultrasonic Sensor	1	1200
	Gas Sensor	1	350
	Temperature Sensor	1	1200
		Total	**15950**

- We Determine the project's Net Present Value (NPV), considering all expenses and advantages over the course of the project.
- And assess the project's allure relative to alternative investments, calculate the Internal

Rate of Return (IRR).

- Also Develop financial projections that outline the expected income, expenses, and cash flows over the project's lifecycle.

- We Calculated the expected return on investment by dividing the net benefits (benefits minus costs) by the total costs.

- Here a positive ROI indicates that the benefits outweigh the costs, suggesting economic feasibility.

- However, The Conduction of sensitivity analyses to understand how changes in key variables (such as costs, revenues, or discount rates) affect the project's economic viability. This helps in identifying critical factors that may significantly impact the project's success.

- We Considered the regulatory and policy environment that may impact the project's economic feasibility.

- We Analyze that how changes in regulations or government policies could affect the project's costs and benefits.

- The Understanding of the market dynamics and demand for the project's outcomes creates a big role in economic analysis of this project.

- At the end, we evaluated the cost-effectiveness of the project by comparing it to alternative solutions or approaches.

A comprehensive economic analysis in this project involves a thorough examination of costs, benefits, risks, and broader economic, social, and environmental considerations to determine the project's overall feasibility and impact.
Lastly, we Calculate the project's payback period to ascertain when it will become profitable.

8.3 Cost Identification

- Initial Investment: We Determined the up-front expenses for developing and putting the monitoring system in place, considering hardware, software, installation, and any upgrades to the infrastructure that may be required.

- Operating and Maintenance Costs: Then we Calculated continuous costs for things like power usage, manpower, data storage, and system monitoring.

Benefits Identification:

- Reduction in Transformer Failures: Here we Calculated how much the likelihood of transformer failures and the related expenses (such as repair or replacement, downtime, and lost income) might be reduced.

- Improved Efficiency: Then we Examined how the monitoring system might improve transformer performance, cutting down on energy waste and operating expenses.

- Extended Transformer Lifespan: We Consider the effect on transformer longevity, which may result in postponed replacement expenses.

- Enhanced Grid Reliability: However, we Assess the benefits of improved grid reliability, including reduced outages and customer satisfaction.

- Environmental Benefits: For Instance, We Include a monetary value for any environmental advantages, such as decreased greenhouse gas emissions from improved efficiency.

Risk Assessment:

- We Identified potential project risks and uncertainties, such as data security concerns, technological obsolescence, and legislative changes.

- Likely we Develop measures for mitigating these risks to determine their financial impact.

8.4 Financial Metrics or aspects

These metrics help stakeholders understand the project's financial health and make informed decisions.

- The present value of all anticipated cash flows (including inflows and outflows) connected to a project is calculated using NPV. When all future cash flows are discounted to their present value using a specific discount rate, it determines whether a project is anticipated to make a net profit or loss. If the NPV is positive, the project is anticipated to be financially advantageous.
- Return On Investment: As a percentage of the initial investment, ROI calculates the return. It is computed by multiplying the result by 100 and dividing the net profit (benefits minus costs) by the initial investment. A stronger return on investment is indicated by a higher ROI.

- Return On Equity: A project's profitability in relation to the equity invested is measured by ROE. It is crucial for projects that are funded by shareholder equity.
- Operating Margin: The percentage of revenue that remains after operating expenses are subtracted is known as the operating margin. It gauges how profitable a project's ongoing activities are.
- Benefit Cost Ratio: BCR is the proportion of a project's overall benefits to its overall expenses. If the BCR is more than 1, the project is financially viable since the benefits outweigh the costs.

When deciding whether to invest in, continue, or withdraw from a project, stakeholders can use these financial measurements to gain important insights into the project's financial success. The exact objectives and setting of the project evaluation will influence the metrics that are selected.

8.5 Conclusion

It is advised to move forward with the Transformer Monitoring System project based on favorable financial metrics, benefits realization, and risk assessment. The initiative is in line with the organization's objectives to increase grid dependability while lowering costs and having less environmental impact. It also presents a strong financial argument, making it a wise investment for the future.

In conclusion, The Transformer Monitoring System project's economic study highlights its potential to produce significant financial gains, increase operational effectiveness, and increase grid dependability. This project is an intelligent investment that will update power distribution networks, guarantee long-term viability, and satisfy the changing demands of the energy industry. The Transformer Monitoring System (TMS) project's economic study shows that it has the potential to provide substantial financial gains while boosting the dependability and effectiveness of power distribution networks.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

At a time when the rate of technological advancement is growing, the development and implementation of innovative methods have turned into an important component of our day-to-day life. One of these advancements is the creation of automated transformer monitoring systems, which have evolved into vital tools for improving the efficiency, safety, and dependability of electrical infrastructure. On the other hand, as technological advancement continues, our awareness of the ethical challenges and professional responsibilities entailed in the creation and application of new technologies grows. Within the context of an automated transformer monitoring system, this paper delves into the concepts of ethics and professional responsibility. Beyond the magic of new technologies, engineers, developers, and organizations must navigate a complex web of ethical conundrums and professional commitments in order to fulfill their responsibilities. The landscape of ethics consists of various components, the most important of which are the protection of personal data, the assurance of environmental sustainability, the observance of regulations, and the promotion of transparency. Throughout the course of this project, we will investigate the professional commitments that lead the construction and implementation of these systems, identify the ethical difficulties that arise, and evaluate the implications for a society in which technology and ethics are intimately tied to one another. The comprehension of these ideas is not merely a matter of personal preference; rather, it is a precondition for achieving the goal of ensuring that technology truly contributes to the enhancement of society while preserving the moral and spiritual foundations upon which it is founded. In a world where technological progress and social responsibility go hand in hand, both must be pursued simultaneously.

The necessity to safeguard sensitive data from unauthorized access and the right to privacy underlie these worries. Comprehensive security measures, such as strong data encryption techniques to protect data during transmission and storage, stringent access controls to limit system access to authorized personnel, and compliance with applicable data protection regulations to ensure lawful and ethical data handling, are a professional obligation.

➢ **Transparency and Informed Consent**

Ethical considerations should be given to transparency and informed consent when installing monitoring systems, especially those that use GSM modules. To be transparent, information about the presence, purpose, and operation of the system must be presented to all stakeholders in an understandable and complete manner. The collected data, its intended use, and any unintended implications are all made clear. In addition to being the moral thing to do, being forthright is good for business because it builds credibility and holds people accountable. Stakeholders, such as end-users and the general public, benefit from transparency because they are better able to make educated decisions and rest easy knowing their data is being used appropriately and securely. For transparency to work, informed consent is essential. Getting people's or groups' permission to collect and use their data is an important part of this process. The importance of respecting people's right to personal freedom and anonymity is emphasized by this moral principle. Experts in the field of monitoring systems need to make sure that individuals have the freedom to consent or refuse to do so and that the consent process is clear, straightforward, and entirely optional. By adhering to these standards, ethical practitioners can better carry out their professional responsibilities, all while encouraging the responsible and open use of monitoring systems equipped with GSM modules.

➢ **Environmental Responsibility:**

Environmental stewardship should be considered in all monitoring activities, but notably in those that are automated. The goal is to lessen the impact these systems have on the environment for the duration of their operation. This commitment requires developing systems that prioritize low energy use, long-term material viability, and moral waste management practices. Energy-efficient designs not only save money in the long run, but also reduce environmental damage by using less power and producing fewer greenhouse emissions. Also, electronic waste is handled in a way that preserves the environment and does not contaminate or harm ecosystems by appropriately disposing of monitoring equipment at the end of its useful life cycle and by complying to existing e-waste disposal standards. Moreover, environmental responsibility includes thinking about the long-term effects of actions. From production to deployment to maintenance to eventual retirement, the system's full environmental impact should be evaluated by experts. Using renewable energy and recyclable components are only two examples of green approaches and materials that can significantly lessen the environmental effect of monitoring systems. Practitioners can uphold their ethical obligation to safeguard the environment while advocating for the widespread use of sustainable infrastructure management technology by including these principles into the design and operation of such systems.

➢ **Compliance with Regulations:**

When operating an automated monitoring system, one of the most important ethical and professional responsibilities is to ensure that all applicable regulations are followed. It involves making a commitment to ensure that these systems comply with all applicable environmental, safety, and data protection legislation and standards. The experts who are in charge of supervising these systems are obligated to be current on the most recent legislative standards applicable to their region and to conduct compliance audits on a regular basis. Practitioners not only uphold the law by maintaining a strong focus on regulatory compliance; they also protect the integrity of the system, limit legal risks, and demonstrate a commitment to ethical and responsible operation in accordance with the highest standards of accountability. These benefits come because of the practitioners' ability to uphold the law.

In summary, one of the most important stages towards guaranteeing the responsible and ethical operation of automated transformer monitoring systems is to identify and handle any ethical issues and professional duties that may arise. Privacy, data security, transparency, data accuracy, environmental responsibility, compliance, safety, conflict of interest, and ethical data management are all extremely important factors to take into account. The maintenance of ethical standards, the cultivation of trust, and the promotion of responsible technology usage can all be accomplished through the incorporation of these concepts into the design and operation of systems.

9.2 Apply ethical issues and professional responsibility

For addressing ethical difficulties and meeting professional requirements in the context of automated transformer monitoring systems, a concentrated effort on the part of engineers, developers, and organizations that operate together is required. The following are some of the ways that putting these values into practice is possible:

- **Data Accuracy and Integrity:**

When it comes to automated transformer monitoring systems, accuracy and integrity of data are two of the most important ethical considerations. The information that is gathered by these systems is then utilized in the process of making crucial decisions. In order for professionals to fulfill their ethical obligations, they are obligated to develop and keep up-to- date rigorous data validation processes as well as calibration schedules for sensors and equipment. This guarantees that the information provided by the system is reliable and devoid of any kind of inaccuracy. Ethical practitioners place a high priority on doing periodic maintenance and quality assurance checks to protect the integrity of the data throughout the lifecycle of the system. By resolving these ethical difficulties, professionals not only ensure that users of the system make informed judgements based on accurate data, but they also maintain the credibility and dependability of the monitoring system, thereby sustaining its ethical foundation in the technological landscape.

- **Privacy and Data Security:**

Privacy and protection of sensitive information are essential pillars upon which an ethical and responsible system can be built. These guiding principles are applicable to automated transformer monitoring systems, and they involve protecting sensitive information that is gathered by the system as well as preserving the privacy rights of persons. It is imperative that data be encrypted not only while in motion but also while it is stored, as this will protect it against unauthorized access and invasions. Access restrictions, efficient authentication methods, and adherence to data protection standards are all necessary components of a data security system. Ethical practitioners have the responsibility of not only preserving the confidentiality of data, but also of being open and forthright with stakeholders about how data is used, preserved, and protected. This responsibility extends beyond only the data itself. Not only do professionals who make protecting users' privacy and data a priority adhere to ethical ideals, but they also succeed in gaining users' and the general public's faith and confidence.

- **Transparency and Informed Consent:**

The ethical operation of automated monitoring systems relies heavily on openness and informed permission. All parties involved, such as end users, regulatory authorities, and local communities, should have full knowledge of the system's goals, features, data collection methods, and usage laws. By being transparent, we can make sure that everyone involved understands how the system functions and the risks it poses to personal information. In contrast, the concept of "informed consent" emphasizes the necessity of obtaining people's or organizations' agreement prior to data collection. To ensure individuals fully understand how their data will be handled, a transparent and opt-in agreement is required.

➢ **Environmental Responsibility:**

In the context of automated monitoring systems, environmental responsibility implies a dedication to minimizing the system's ecological footprint at every stage of its existence. The use of renewable energy, efficient building plans, and careful trash disposal are all examples of how this moral ideal can be put into practice. System designers should prioritize renewable energy and energy-efficient parts to cut down on carbon emissions and utility bills. In addition, a more sustainable approach to technology deployment is promoted by adhering to proper e-waste disposal standards and supporting the recycling of electronic equipment at the end of its life cycle. Professionals who respect the autonomy and privacy of their clients and customers and who include transparency and informed consent into their practices demonstrate a dedication to ethical data handling.

➢ **Emergency Response and Safety**:

The ethical function of the automated transformer monitoring systems requires careful attention to emergency response and safety. These systems should be built to immediately detect and report any transformer or infrastructure-related anomalies, malfunctions, or safety concerns. Ethical professionals place a premium on the development of reliable alarm systems, emergency protocols, and routine training and drills to enable a rapid response to catastrophic emergencies. In addition to safeguarding personnel and communities, professionals who uphold these principles contribute to the security of critical infrastructure and public safety by operating these systems in accordance with the strictest possible safety measures.

9.3 Conclusion

In conclusion, ethics and professional obligations are the cornerstones of ethical and sustainable technical advancement, particularly in complex systems such as automated transformer monitoring. This is especially true in the context of complex systems. This is especially the case within the domain of electrical engineering. These ethical considerations include privacy, data security, transparency, data accuracy, environmental responsibility, compliance, safety, conflicts of interest, and ethical data management, among other things. Not only can we ensure that these systems are used in an ethical manner, but we can also establish confidence, credibility, and accountability in them by methodically embedding these principles into the design, operation, and maintenance of such systems. This allows us to do more than just ensure that these systems are utilized in an ethical manner. To strike a balance between the need to innovate and the preservation of rights, privacy, and safety, which will ultimately lead to the development of a more responsible and sustainable approach to technology, it is crucial for us to maintain these ethical norms in an environment in which technology is undergoing rapid change. This will allow us to achieve our goal of striking a balance between the two

Transformer management has absolutely been revolutionized by the introduction of automated transformer monitoring systems. This is without a doubt one of the most significant advancements in the field. These technologies have completely altered the method in which organizations maintain track of the essential transformer assets they possess. Before the advent of this technology, it was usually difficult to reach the level of precision and adaptability that is necessary for the efficient operation of transformers. This is because of the fact that transformers are inherently inflexible devices. On the other hand, the likelihood of expensive downtime and equipment failure has drastically decreased because of real-time monitoring, remote access, and quick alarm systems. This has resulted in significant cost savings. This technology allows organizations the freedom to better divide their available resources and to execute preventative maintenance in a proactive way because of its capacity to gather and evaluate previous data. This is made possible because of the technology's capacity to collect and assess historical data. The application of these technologies, therefore, not only leads to cost reductions, but it also results in overall gains in output levels.

One of the primary benefits of automated transformer monitoring is its scalability, which makes it possible to adapt it for utilization in a variety of circumstances, ranging from individual transformers to entire fleets of transformers. This makes it one of the most notable advantages of automated transformer monitoring. Because of this versatility, automated transformer monitoring is one of the traits that is the most outstanding. It is also simple to link with control systems that are already in place, which adds another dimension of variety to its capabilities. Because of this, it is possible to deploy it effectively in a wide variety of different contexts, it is imperative that the significance of effectively putting this technology into practice be emphasized. This should not be ignored in any way. Even if it has the potential to bestow a huge number of advantages, the success of its implementation is predicated on the fact that it is carried out in the appropriate manner. This is demonstrated by the significant reduction in operational expenses, in addition to the assurance that everyone involved will remain risk-free.

Chapter 10: Conclusion and Future Work

10.1 Project summary/Conclusion

Transformer management has absolutely been revolutionized by the introduction of automated transformer monitoring systems. This is without a doubt one of the most significant advancements in the field. These technologies have completely altered the method in which organizations maintain track of the essential transformer assets they possess. Before the advent of this technology, it was usually difficult to reach the level of precision and adaptability that is necessary for the efficient operation of transformers. This is because transformers are inherently inflexible devices. On the other hand, the likelihood of expensive downtime and equipment failure has drastically decreased because of real-time monitoring, remote access, and quick alarm systems. This has resulted in significant cost savings. This technology allows organizations the freedom to better divide their available resources and to execute preventative maintenance in a proactive way because of its capacity to gather and evaluate previous data. This is made possible because of the technology's capacity to collect and assess historical data. The application of these technologies, therefore, not only leads to cost reductions, but it also results in overall gains in output levels.

One of the primary benefits of automated transformer monitoring is its scalability, which makes it possible to adapt it for utilization in a variety of circumstances, ranging from individual transformers to entire fleets of transformers. This makes it one of the most notable advantages of automated transformer monitoring. Because of this versatility, automated transformer monitoring is one of the traits that is the most outstanding. It is also simple to link with control systems that are already in place, which adds another dimension of variety to its capabilities. Because of this, it is possible to deploy it effectively in a wide variety of different countries. It is imperative that the significance of effectively putting this technology into practice be emphasized. This should not be ignored in any way. Even if it has the potential to bestow a huge number of advantages, the success of its implementation is predicated on the fact that it is carried out appropriately. This is demonstrated by the significant reduction in operational expenses, in addition to the assurance that everyone involved will remain risk-free.

In essence, due to the difficulty and stringency of modern transformer operations, it would be an undertaking of insurmountable difficulty, if not outright impossible, to try to run them without the support of an automated monitoring system. This is because of the complexity and stringency of modern transformer operations. These systems provide businesses with the capacity to enhance the maintenance of their transformers, which, in the long run, leads to better efficiency, increased safety, and a reduction in the expenses involved with operating transformers. These accomplishments are within reach because automated transformer monitoring systems bring cutting-edge capabilities to the table in the areas of monitoring, communication, and analytics. These capabilities make it possible for these achievements to be realized. As long as the rate of technological advancement stays the same, we should be able to anticipate much more important upgrades and benefits in the administration of transformer assets and the overall dependability of electrical grids.

10.2 Future work

The expansion and refining of automated transformer monitoring systems are at the forefront of assuring the stability and efficiency of electrical grids in an era characterized by rapid technology breakthroughs and a growing dependence on essential infrastructure. These systems have been useful in the past for delivering real-time insights into the health of transformers, but there is still a great deal of room for further development. To bring about a new era of smarter and more resilient grid management, this developing field invites researchers, engineers, and industry stakeholders to investigate paths including improved data analytics, cybersecurity measures, edge computing, and the integration of IoT sensors, among others. Future work in automated monitoring systems is explored in this essay, along with the opportunities and difficulties that lie ahead in our pursuit to optimize power distribution networks for a sustainable and digitally linked future. Several areas of this field need further exploration and development as technology advances:

➢ **Enhanced Data Analytics**:

Implementing complex algorithms and techniques, such as machine learning and deep learning models, in automated transformer monitoring systems allows for enhanced data analytics and the extraction of useful insights from the vast amounts of data produced by transformers. By spotting subtle patterns, abnormalities, and degradation trends in transformer performance, these sophisticated analytics hope to enhance problem detection accuracy and predictive maintenance capabilities. Operators can improve the dependability and efficiency of the electrical grid while decreasing downtime and maintenance costs by using data analytics to obtain a better understanding of the transformer's health, predict possible difficulties, and optimize maintenance schedules.

➢ **Integration with IoT Sensors**:

Adding IoT sensors to automated transformer monitoring systems means connecting special sensors to the transformer to get more information about its health in real-time. These monitors, which can measure things like temperature, humidity, and the quality of the oil, give a complete picture of the health and performance of the transformer. By adding these Internet of Things (IoT) sensors, operators can get useful information that helps them find possible problems early, improve repair schedules, and make sure the transformer works well, which improves the reliability of the electrical grid.

➢ **Cybersecurity Measures**:

In automated transformer tracking systems, putting cybersecurity measures in place means taking steps to protect the system from cyber threats and unauthorized access. This means adding security layers like encryption to protect the data sent from transformers, using strong login methods to make sure that only authorized people can get into the system, and updating the software of the system regularly to fix any holes. By focusing on cybersecurity, we make sure that important infrastructure, like transformers, is safe from hacking and cyberattacks. This keeps the electrical grid running smoothly and prevents possible problems.

➢ **Remote Control and Diagnostics**:

The capacity to control and diagnose issues with transformers remotely is required for remote control and diagnostics in automated transformer monitoring systems. This enables transformers to be managed and investigated from a distance. It gives operators and maintenance teams the ability to remotely modify the settings of a transformer, execute orders, and diagnose problems in real time, all without having to be physically present at the location of the transformer. This feature streamlines maintenance operations, shortens response times to failures, and minimizes the need for on-site visits. As a result, overall efficiency is improved, and rapid remedial actions are ensured, when necessary, which increases the electrical grid's reliability.

➢ **Battery Management and Cost Optimization:**

In automated transformer monitoring systems, battery management means taking care of the power supply to the modules in a way that makes sure they always have a stable source of energy to keep running. Proper battery management is important for system reliability, especially in remote areas with unstable power sources, because it stops data loss and system downtime. Additionally, cost optimization works on finding ways to deploy and maintain these systems on a wide range of transformers, including smaller or older ones, that don't cost too much. By taking care of both battery management and cost optimization, we can make transformer tracking more sustainable and affordable, as well as make sure data is collected without interruption and the grid is more reliable.

➢ **AI-Based Decision Support**:

AI-based decision support in automated transformer monitoring systems means using artificial intelligence and machine learning algorithms to look at data and give operators and repair staff actionable insights. These AI-powered systems can automatically find patterns, outliers, and possible problems in the way transformers work. This lets people make decisions faster and with more information. AI-based decision support improves the efficiency of transformer management, cuts down on downtime, and makes the electrical grid more reliable and resilient. It does this by giving recommendations for maintenance actions, predictions for future performance, and insights into operational optimization.

➢ **Data Visualization and Reporting**:

The term "data visualization and reporting" is used to describe the process by which data from automated transformer monitoring systems is presented in a way that is easy to read and comprehend. Making dashboards and reports that are easy to read and understand is a crucial part of this process. To better understand the patterns in the transformer's health and performance, these data can be visualized using graphs, charts, and other graphical representations. Transform the monitoring system's findings into timely actions that increase transformer reliability and grid management with the help of an effective data visualization and reporting system.

Automated transformer monitoring systems, which can improve electrical grid efficiency and reliability, require continuous R&D in the above domains. As our energy landscape changes, including the integration of renewable energy sources, the electrification of varied industries, and climate change grid resilience, these systems must be upgraded. These monitoring systems can detect problems for preventative maintenance and grid optimization using advanced data analytics. Data integrity and grid stability depend on effective cybersecurity to protect important infrastructure from intrusions. IoT connection helps identify transformer health issues before they escalate. Cost optimization is necessary to make these systems accessible and scalable across urban and remote transformers. We invest in R&D to make automated transformer monitoring systems the backbone of modern grid management, enabling a seamless transition to a cleaner, more reliable, and resilient energy future. These solutions help utilities achieve global sustainability goals and improve power quality and dependability for communities and business.

. Chapter 11: Identification of Complex Engineering Problems and Activities

11.1 : Identify the attribute of complex engineering problem (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	✓
P3	Depth of analysis required	✓
P4	Familiarity of issues	✓
P5	Extent of applicable codes	✓
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	

11.2 : Provide reasoning how the project address selected attribute (EP)

P1: Depth of knowledge required

To work in this project first we need to understand how the transformer works and what type of transformer we are working on. Also, how we can address the problem. Knowledge about suitable sensors, software is also important. As we know a power transformer is very complex yet very crucial and without fully understanding the issues related to a transformer, we can't build a system that can monitor it. So, we need to have a complete depth of knowledge.

P2: Range of conflicting requirements

We have used multiple sensors in both of our designs, so connecting those to the system and collecting data using codes (Arduino IDE, Python) was complicated.

P3: Depth of analysis required

To understand the issues hidden and unhidden we were required to do a complex analysis in every step. Taking data related to the systems was needed and done accordingly.

P4: Familiarity of issues

Power transformers are very expensive and important. In our daily life we need electricity for almost everything. So, if we can monitor the health of the transformer such as the current, voltage, temperature, oil level and humidity. we can prevent the damage because of the internal problems. Also, the damage can cause problems in human life as well as the environment.

P5: Extent of applicable codes

While preparing the project we came to know about applicable codes of IEEE standard. For each component and various systems, we learned there are different applicable codes which we had to follow.

11.3 Identify the attribute of complex engineering activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	✓
A2	Level of interaction	✓
A3	Innovation	
A4	Consequences for society and the environment	✓
A5	Familiarity	✓

11.4 Provide reasoning how the project address selected attribute (EA)

A1: Range of resource

To make this system work efficiently, we have to choose the components wisely. We have to use the components which are easily available in our country or easy to get. Also, we have to check if those are cost effective.

A2: Level of interaction

The system can be new to many people in our country. So that we will need expert people to work on this. To use this system nation wise we have to make everyone aware of it and encourage them to use the system for better and long-time use.

A4: Consequences for society and the environment

Monitoring the health of power transformers can affect our society and environment greatly. As we will be able to know about the condition of the transformer at any time by looking at the data report. So that many casualties/damages to the society can be avoided. Also, transformer oil can be hazardous to human life and nature. Also, because of transformer damage and breakdown, the electricity can be gone for a very long time. All of this can be prevented if we can take precaution.

A5: Familiarity

A Transformer health Monitoring system can be a great addition. But , many can oppose the idea as they are quite new to it. For that we have to reach out to everyone and make them understand what we can achieve with this.

Attributes of Complex Engineering Problems (EP)

	Attributes	**Put tick (√) as appropriate**
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	✓
P3	Depth of analysis required	✓
P4	Familiarity of issues	✓
P5	Extent of applicable codes	✓
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	

Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	✓
A2	Level of interaction	✓
A3	Innovation	
A4	Consequences for society and the environment	✓
A5	Familiarity	✓

References

[1] W. K. A. Hasan, A. Alraddad, A. Ashour, Y. Ran, M. A. Alkelsh, and R. A. M. Ajele, “Design and Implementation Smart Transformer based on IoT”, in *2019 International Conference on Computing, Electronics & Communications Engineering (iCCECE)*, Aug. 2019, pp. 16–21. doi: 10.1109/iCCECE46942.2019.8941980.

[2] P. S. Emi, R. Sivasankari, P. R. Kumar, R. Prabha, J. Jayageetha, and A. Karhikeyan, “Fault Detection in Transformer Using GSM Technology”, in *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)*, Mar. 2019, pp. 868–873. doi: 10.1109/ICACCS.2019.8728502

[3] D. Srivastava and M. M. Tripathi, “Transformer Health Monitoring System Using Internet of Things”, in *2018 2nd IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, Oct. 2018, pp. 903–908. doi: 10.1109/ICPEICES.2018.8897325.

[4] R. R. Pawar, P. A. Wagh, and S. B. Deosarkar, “Distribution transformer monitoring system using Internet of Things (IoT)”, in *2017 International Conference on Computational Intelligence in Data Science(ICCIDS)*, Jun. 2017, pp. 1–4. doi: 10.1109/ICCIDS.2017.8272671.

[5] R. R. Pawar and S. B. Deosarkar, “Health condition monitoring system for distribution transformer using Internet of Things (IoT)”, in *2017 International Conference on Computing Methodologies and Communication (ICCMC)*, Jul. 2017, pp. 117–122. doi: 10.1109/ICCMC.2017.8282650.

[6] S. Bashi, N. Mariun, and A. Rafa, “Power Transformer Protection Using Microcontroller-Based Relay”, *Journal of Applied Sciences*, vol. 7, Dec. 2007, doi: 10.3923/jas.2007.1602.1607.

[7] V. Waghmare, A. Agarwal, R. Rusia, A. Wankar, P. Atkari, and M. Kumare, “TRANSFORMER PROTECTION USING MICROCONTROLLER BASED RELAY AND MONITORING USING IOT AND GSM”, *Journal of Research in Engineering and Applied Sciences*, vol. 05, pp. 65–70, Apr. 2020, doi: 10.46565/jreas.2020.v05i02.005.

[8] S. Rahman, S. K. Dey, B. K. Bhawmick, and N. K. Das, “Design and implementation of real time transformer health monitoring system using GSM technology”, in *2017 International Conference on Electrical, Computer and Communication Engineering (ECCE)*, Feb. 2017, pp. 258–261. doi: 10.1109/ECACE.2017.7912915.

[9] M. Tripathy, R. P. Maheshwari, and H. K. Verma, “Power Transformer Differential Protection Based On Optimal Probabilistic Neural Network”, *IEEE Transactions on Power Delivery*, vol. 25, no. 1, pp. 102–112, Jan. 2010, doi: 10.1109/TPWRD.2009.2028800.

[10] A.-R. Al-Ali, A. Khaliq, and M. Arshad, "GSM-based distribution transformer monitoring system", in *Proceedings of the 12th IEEE Mediterranean Electrotechnical Conference (IEEE Cat. No.04CH37521)*, Dubrovnik, Croatia: IEEE, 2004, pp. 999– 1002. doi: 10.1109/MELCON.2004.1348222.

[11] "IEEE SA - IEEE 802.11-2016," *IEEE Standards Association*. [Online]. Available: https://standards.ieee.org/ieee/802.11/5536/ .

[12] "IEEE SA - IEEE C37.241-2017," *IEEE Standards Association*. [Online]. Available: https://standards.ieee.org/ieee/C37.241/4858/ .

[13] "IEEE SA - PC57.143," *IEEE Standards Association*. [Online]. Available: https://standards.ieee.org/ieee/C57.143/6961/ .

[14] "IEEE SA - IEEE C37.91-2021," *IEEE Standards Association* https://standards.ieee.org/ieee/C37.91/5904/ .

[15] "Pour point of different insulating liquids. | Download Scientific Diagram". Accessed: Dec. 07, 2023. [Online]. Available: https://www.researchgate.net/figure/Pour- point-of-different-insulating-liquids_tbl4_304367093

[16] Z. Moravej, "Condition Monitoring Techniques of Power Transformers: A Review," Jan. 2015 [Online]. Available: https://www.academia.edu/82058561/Condition_Monitoring_Techniques_of_Power_Transformers_A_Review .

[17] S. Ren, X. Yang, W. Yang, B. Xi, and X. Cao, "Research on Insulation Condition Monitoring System for Power Transformers", in *2008 International Conference on Condition Monitoring and Diagnosis*, Apr. 2008, pp. 1005–1007. doi: 10.1109/CMD.2008.4580451.

[18] "[PDF] Condition Monitoring of Distribution Transformer Using Internet of Things (IoT) | Semantic Scholar." [Online]. Available: https://www.semanticscholar.org/paper/Condition-Monitoring-of-Distribution-Transformer-of-Parihar/666b691830dc15b7d0afa3d91c25cb08572de89f .

[19] "Research Gate." [Online]. Available: https://www.researchgate.net/publication/367157004_Design_and_Implementation_of_Transformer_Health_Monitoring_using_IOT/link/63c3a649e922c50e9997870e/download .

[20] "130+ million publications organized by topic on Research Gate". Accessed: Dec. 07, 2023. [Online]. Available: https://www.researchgate.net/directory/publications

[21] "What is Buchholz Relay? Working, Diagram & Construction – Electrical Workbook". Accessed: Dec. 07, 2023. [Online]. Available: https://electricalworkbook.com/buchholz-relay/

[22] "Buchholz Relay – Principle, Construction and application". Accessed: Dec. 07, 2023. [Online]. Available: https://www.electricalclassrooSm.com/buchholz-relay- working-principle/

[23] "Faulty sensor detection using multi-variate sensors in internet of things (IoTs) | Omar | Indonesian Journal of Electrical Engineering and Computer Science". Accessed: Dec. 07, 2023. [Online]. Available: https://ijeecs.iaescore.com/index.php/IJEECS/article/view/211

[24] Adnanaqeel, "Introduction to Arduino IDE - The Engineering Projects". Accessed: Dec. 07, 2023. [Online]. Available: https://www.theengineeringprojects.com/2018/10/introduction-to-arduino-ide.html

Index

Logbook

Logbook (P)

Date/Time	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
10.10.2022	All members	To find a suitable project topic	All	
11.10.2022	ATC meeting	Introductory session with Overview on topic choosing	All	suggested to gather more information about the projects.
13.10.2022	All members	Discussion on everyone is gathered idea and initially choosing a few topics	All	
20.10.2021	ATC meeting	Proposed the initial ideas	All	
27.10.2022	ATC meeting	Proposed a project on Transformer Monitoring System and Protection	All	Gave idea about power transformer and the monitoring system and suggested further research.
30.10.2022	All members	Prepared draft copy of Concept notes on "Transformer Monitoring System for the Protection of Transformer Faults."	All	
01.11.2022	All members	Preparing slides for presentation 1	All	
02.11.2022	All members	Presentation 1	All	Suggested to change the first design approach.
02.11.2022	ATC meeting	Discussion on the after presentation feedbacks	All	Suggested for in depth knowledge gathering on the design approaches.
04.11.2022 06.11.2022	All members	Research on Designing Transformer Protection System papers	All	
08.11.2022	ATC Meeting	Proposed the idea of final 3 design approaches	Task 1. Literature Review: Faiza & Shahtaz	recommend for working on AII based and Microcontroller ones.
10.11.2022	All	Preparing "draft copy of	All	

12.11.2022	members	concept note“““		
14.11.2022	ATC members	Discussion on “draft copy of concept notes“““	All	Advised to add some changes
17.12.2022 18.12.2022 19.12.2022	All members	Making final copy of concept note	All	
20.11.2022	All members	Final Concept Note submission	Shahtaz	
25.12.2022 26.11.2022	All members	Discussion on choosing the components and preparing the plan	Sarthak, Shahtaz & Purno	
02.12.2022	ATC meeting	Discussion on components	Purno	Recommended to do more study on specifications and prepare component level flowchart
05.12.2022	All members	Analyzing specifications and component level flowchart	Task 1. Specification: Minhajur Task 2. Component Level: Sarthak	
05.12.2022	All members	Making Budget	Sarthak & Minhajur	
08.12.2022 09.12.2022	All members	Making “Progress presentation 2“““ slides	Shahtaz,Faiza & Purno	
11.12.2022	ATC meeting	Deep discussion on overall project and about Algorithm	All	Complete the report and slides as recommended
12.12.2022	All members	Planning and dividing the rest of the works for final presentation and submission	All	
13.12.2022	All members	Preparing the final slide	Shahtaz,Faiza & Purno	
14.12.2022	All members	Final Progress presentation	All	
14.12.2022 15.12.2022 16.12.2022	All members	Preparing the Final proposal Paper	All	

17.12.2022	All members	Giving final touch on report according to ATC‟s suggestion	All	

Logbook (D)

Date/Time	Attendee	Summary of Meeting Minutes	Responsible	Comment By ATC
Jan 26, 2023 11:00 am	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Task 1: Attending the first class of EEE400D/402D & meeting with Nazmul Huda sir.	Task 1 done by: 1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Start the designs and use suitable software for simulation.
Jan 28, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	1. Group discussion on the distribution 2. Plan on Design 2	Done by: 1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	**N/A**
Feb 2, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Discussion on the progress ideas of design 2	Task done by ALL.	**N/A**
Feb 6, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Working on design 2	Task done by ALL.	**N/A**
Feb 9, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed	Meeting with Nazmul Huda sir & completing the Proteus schematic for design 2	**Done by:** 1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed	**N/A**

Feb 12, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Coding for design 2	Done By: 1. Sarthak Das 2. Minhajur Rahaman	**N/A**
Feb 18, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Checking the progress of design 2 Checking for the issues	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	**N/A**
Feb 22 , 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Discussion for design 1		**N/A**
Feb 25, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Distributing the writing for progress presentation	Done by ALL	**N/A**
Feb 28, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	**Tasks:** 1. Background research, objective. 2. Multiple design approaches, design 1 3. requirements, constraints,budge,specification	**Done by:** Task 1: Mumtahina Tasnim Purno Task 2: Shahtaz Zahra Sayeed, Faiza Ahmed Task 3: Sartak Das, Minhajur Rahman	**N/A**
March 2, 2023 11:00 a.m.	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Attending progress presentation	1. Shahtaz Zahra Sayeed 2. Faiza Ahmed 3. Sarthak Das 4. Minhajur Rahaman	Check the design requirements and specification.

Mar 12, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Discussion the progress on design 2 And make some changes on design 1	Done by ALL.	**N/A**
Mar 13, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Making the schematic of design 1	Done by: Sarthak das, Minhajur Rahman	**N/A**
Mar 18, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Meeting to discuss the overall progress on designs	Done by ALL.	**N/A**
Mar 20, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed	Task: Test run design 1	Done By: Purno, Zahra, Faiza	**N/A**
Mar 22, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Task: Solution for design 3	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	**N/A**
Mar 23, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Task: Meeting Nazmul Huda sir	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Discard design 3 as it required Buchholz relay which is both expensive and software simulation is not possible.
Mar 28, 2023	1. Mumtahina Tasnim Purno	Task: Divide the writing	Done by all.	**N/A**

	2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	work for draft report		
Apr 2, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Meeting on overall progress discussion.	Done by All.	**N/A**
Apr 6, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Task: Consultation with Nazmul Huda sir & completing the draft	Done by ALL.	If necessary, make a 3D model
Apr 8, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Writing explanation for system design and analysis for design 1	Done by: Purno, Sarthak	N/A
Apr 9, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Design analysis for design No.2	Done by: Faiza, Zahra	N/A
Apr 12, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	Discussion on overall report.	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman	N/A
Apr 13, 2023	1. Mumtahina Tasnim Purno	Discussion on overall effort	Done by ALL.	N/A

	2. Shahtaz Zahra Sayeed 3. Faiza Ahmed 4. Sarthak Das 5. Minhajur Rahaman			
Apr 15, 2023	1. Mumtahina Tasnim Purno 2. Shahtaz Zahra Sayeed 3. Faiza Ahmed	Writing report	Done by ALL.	N/A

Log book (C)

Date/Time	Attendee	Summary of meeting minutes	Responsible	Comment by ATC
25.06.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	meeting on choosing optimal design that is the design approach 1.	ALL	N/A
28.06.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Meeting with ATC to consult about our choice of design.	ALL	Gave some suggestions on which design will be efficient to work on.
29.06.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	We discussed and collected information on how to implement the hardware setup	ALL	N/A
01.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Further discussion on what type of tools and components we need	ALL	N/A
02.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Purchasing the components	1. Sarthak 2. Purno 3. Rafsun	N/A
03.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Developing project	ALL	N/A
07.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Developing project	ALL	N/A
11.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Preparation for progress presentation	ALL	N/A
13.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Progress presentation	ALL	N/A

15.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Development of project	ALL	N/A
20.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Project development	ALL	N/A
24.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Testing and correcting	ALL	N/A
30.07.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Testing	ALL	N/A
07.08.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Meeting with ATC to show the developed project	1. Zahra 2. Purno 3. Rafsun 4. Sarthak	Suggested us to change our project title from „Design and implementation of a power transformer monitoring system for the protection of transformer faults" to „Design and implementation of an automated transformer monitoring system"
24.08.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Poster making	Zahra	N/A
26.08.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Project showcase	ALL	Work on the GSM part of the project
04.09.2023	1. Zahra 2. Purno 3. Faiza 4. Rafsun 5. Sarthak	Making final draft report	ALL	N/A

Related code/theory

The following code will be a monitoring system for a transformer that measures several parameters such as temperature, humidity, oil level, gas presence, voltage, and earth current. The system displays the values on an LCD screen and sends SMS alerts if certain conditions are met. The system uses various sensors such as the DHT11 sensor to measure temperature and humidity, an ultrasonic sensor to measure oil level, an ACS712 current sensor to measure earth current, and an energy monitor to measure voltage.

In the setup function, the code initializes the sensors and LCD display, and prints an introductory message on the LCD.

The **setup ()** function initializes the different sensors, sets the LCD screen and prints the project title and a brief description.

The **loop ()** function runs continuously and reads data from the sensors. It then displays the data on the

LCD screen and calls the **condition ()** function to check if any of the parameters exceed the set limits. If any of the parameters exceed the set limits, the **SMS ()**, **sms1()**, or **sms2()** function sends an SMS to a specific phone number.

The **SMS ()** function sends an SMS if the transformer temperature exceeds the set limit. The **sms1()** function sends an SMS if the oil tank is full, and the **sms2()** function sends an SMS if the oil level is low.

The **condition ()** function checks if the temperature exceeds 50 degrees Celsius, the oil level is below 20%, or the oil tank is full. If any of the conditions are met, the corresponding function is called to send an SMS.

In the loop function, the code reads the values from the sensors and calculates the respective parameter values. It then displays the values on the LCD screen and calls a condition function to check if any of the parameters exceed certain threshold values. If a parameter exceeds its threshold, the condition function calls and SMS function to send an alert to a designated mobile number.

The SMS functions use the SIM900 module to send text messages. The SMS function first sets the SIM900 module to text mode, then sends the recipient's phone number and the message to send, and finally sends an ASCII code to indicate the end of the mess.

```
#include  <Wire.h>
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>
#include "EmonLib.h"
#include "DHT.h"

#define DHTPIN A0
EnergyMonitor emon1;

LiquidCrystal lcd(7, 6, 5, 4, 3, 2);
SoftwareSerial SIM900(9, 10);
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

const int trigPin = 12;  // Trigger Pin of Ultrasonic Sensor
const int echoPin = 11; // Echo Pin of Ultrasonic Sensor
long duration;
int OilLevel;
```

```
int delayTime = 500;

int EarthCurrent; float
SensorReadEarth;
float sensitivity = 0.185;



int temp;
float TempSensorPin = A0; float vout;



void setup() {
    // put your setup code here, to run once:
    pinMode(TempSensorPin, INPUT); pinMode(trigPin,
    OUTPUT); pinMode(echoPin, INPUT); emon1.voltage(A3,
    187, 1.7); Serial.begin(9600);
    SIM900.begin(9600);
    dht.begin();

    Serial.println(" REMOTE TRANSFORMER MONITORING");
    lcd.begin(20, 4); lcd.print("PROJECT
    WORK"); lcd.setCursor(2, 1);
    lcd.print("REMOTE"); lcd.setCursor(9,
    1); lcd.print("MONITORING");
    lcd.setCursor(4, 2);
    lcd.print("TRANSFORMER");
    delay(delayTime); lcd.clear();
}

void loop() {

    //temperature && Humidity//
    // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)
    int h = dht.readHumidity();
    // Read temperature as Celsius (the default) int t =
    dht.readTemperature();

    // Voltage measurement
    emon1.calcVI(20, 2000);                    // Calculate all. No.of half wavelengths (crossings), time-
out
    int Voltage = emon1.Vrms; //extract Vrms into Variable


    //EARTH CURRENT//
    SensorReadEarth = analogRead(A1) * (5.0 / 1023.0);                          //We read the
sensor output
    EarthCurrent = (SensorReadEarth - 2.5) / sensitivity; //Calculate the current value for earth
```

```
    // SENSING OIL LEVEL//
    digitalWrite(trigPin, LOW); delayMicroseconds(2);
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10); digitalWrite(trigPin,
    LOW); duration = pulseIn(echoPin, HIGH);
    OilLevel = duration * 0.034 / 2;
    OilLevel = map(OilLevel, 0, 1023, 0, 100);

    //LCD PRINTING//

    lcd.setCursor(0, 0); lcd.print("Temp:");
    lcd.print(t); lcd.write(223); lcd.print("C
    ");

    lcd.setCursor(10, 0);
    lcd.print("Humi:"); lcd.print(h);
    lcd.print("% ");

    lcd.setCursor(0, 1); lcd.print("Oil
    Level:"); lcd.setCursor(10, 1);
    lcd.print(OilLevel); lcd.print("%
                                  ");

    lcd.setCursor(0,2); lcd.print("GAS: ");
    if (digitalRead(A2) == 1) { lcd.print("YES ");
    } else lcd.print("NO  ");

    lcd.setCursor(0, 3);
    lcd.print("V: ");
    lcd.print(Voltage);
    lcd.print("V                    ");

    lcd.setCursor(10, 3);
    lcd.print("I: ");
    lcd.print(Current,2); lcd.print("A
                                    ");
    delay(200);

    condition();
}

void sms() { SIM900.print("AT+CMGF=1\r");
    SIM900.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    Serial.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
```

```
    SIM900.println("HIGH TRANSFORMER TEMPERATURE");                    // message to send
    Serial.println("HIGH TRANSFORMER TEMPERATURE");
    SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26 Serial.println((char)26);
    SIM900.println();
}

void sms1() { SIM900.print("AT+CMGF=1\r");
    SIM900.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    Serial.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    SIM900.println("OIL TANK FULL");                                   // message to send
    Serial.println("OIL TANK FULL");
    SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26 Serial.println((char)26);
    SIM900.println();
}

void sms2() { SIM900.print("AT+CMGF=1\r");
    SIM900.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    Serial.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    SIM900.println("LOW OIL LEVEL");                                   // message to send
    Serial.println("LOW OIL LEVEL");
    SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26 Serial.println((char)26);
    SIM900.println();
}

void sms3() { SIM900.print("AT+CMGF=1\r");
    SIM900.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    Serial.println("AT + CMGS = \"+8801521202326\""); // recipient's mobile number
    SIM900.println("EARTH FAULT CURRENT");                             // message to send
    Serial.println("EARTH FAULT CURRENT");
    SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26 Serial.println((char)26);
    SIM900.println();
}

//CONDITIONS
void condition() { if (temp >
    75) {
        lcd_tempPrint(); sms();
        delay(300);
    }

    if (OilLevel > 80) {
        lcd_oilLevelFULLPrint(); sms1();
```

```
    delay(500);
  }

  else if (OilLevel < 30) {
    lcd_oilLevelLOWPrint();
    sms2();
    delay(300);
  }
}


// LCD PRINTING CONDITION//

void lcd_oilLevelFULLPrint() {
  lcd.clear();
  lcd.setCursor(1, 1);
  lcd.clear(); //if condition temp for it to print.
  lcd.print("OIL TANK FULL");
}

void lcd_oilLevelLOWPrint() {
  lcd.clear();
  lcd.setCursor(0, 2);
  lcd.clear(); //if condition temp for it to print.
  lcd.print("OIL LEVEL LOW");
}

void lcd_tempPrint() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.clear(); //if condition temp for it to print.
  lcd.print("HIGH TEMPERATURE");
}
```