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TRANSFORMER HEALTHINESS MONITORING SYSTEM

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Abstract: Here this document presents design and implementation of a mobile embedded system to measure load currents, overvoltage, transformer oil level and oil temperature. This is implemented by using on-line measuring system using Internet of Things (IOT), with single chip Arduino microcontroller and sensors. It is installed at the distribution transformers i.e. The output values of sensors are processed and recorded in the system memory. System programmed with some predefined instructions to check abnormal conditions. If there is any abnormality on the system, details are automatically updated through serial communication. This Internet of Things (IOT) will help the utilities to optimally utilize transformers and identify problems before any catastrophic failure occurs. Thus online-measuring system is used to collect analyse temperature data overtime. So, Transformer Health Measuring will help to identify or recognize unexpected situations before any serious failure which leads to a greater reliability and significant cost savings.

Keywords: Transformer health, Arduino Uno, Bluetooth module, Ultrasonic Sensor, LM35, Internet of Things.

1.INTRODUCTION

Transformer is one of the important electrical equipment that is used in power system. Monitoring transformer for the problem before they occur can prevent faults that are costly to repair and result in a loss of electricity. Currently, failure of the transformer can be detected by colour changing of silica gel and decreasing the quality and viscosity of oil. The main aim of the Transformer Healthiness Monitoring System is to develop a real-time monitoring solution that enhances the reliability, efficiency, and lifespan of transformers by continuously tracking critical parameters such as temperature, oil level, current, and voltage. The system utilizes various sensors to collect data and transmits it wirelessly via Bluetooth to a mobile device, enabling remote monitoring and timely maintenance interventions. are done. Despite the circuit breaker being in good condition, the system experiences increased downtime due to the time-based maintenance method. Furthermore, the cost of maintaining circuit breakers goes up when specialized diagnostic tools are used.

By implementing this system, the project seeks to:

- Prevent transformer failures by detecting overheating, oil depletion, and electrical anomalies early.
- Reduce maintenance costs through predictive maintenance rather than reactive repairs.
- Enhance operational efficiency by providing real-time data to engineers and technicians.
- Improve safety by minimizing risks associated with transformer malfunctions, such as electrical fires or power outages.
- Enable remote monitoring to reduce manual inspection efforts and increase accessibility to transformer health data.

2. MATERIALS AND METHODS

2.1 Working Principle

The system monitors temperature, oil level, voltage, and current using an Arduino Uno and various sensors. A 230V AC supply is stepped down, converted to 12V DC, and powers the circuit. The LM35 sensor measures temperature, the HC-SR04 ultrasonic sensor detects oil level, the B25 sensor measures voltage, and the ACS712 sensor monitors current. Data is displayed on a 16×2 LCD and transmitted via the HC-05 Bluetooth module to a mobile application for real-time monitoring.

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2.1.1 Temperature Fault
Excessive load current alone may not result in damage to the transformer if the absolute temperature of the windings and transformer oil remains within specified limits. Transformer ratings are based on a 24-hour average ambient temperature of 45°C. Due to over voltage and over current, temperature of oil increases which causes failure of insulation of transformer winding.

2.1.2 Oil Level Fault
Oil mainly used in transformer for two purposes one is for cooling of transformer and another use is for insulation purpose. When temperature of transformer goes high, oil level in transformer tank decreases due to heating effect. For normal operation of transformer oil level should maintain at required level. If oil level decreases beyond required level, it affects cooling and insulation of the transformer.

2.2 Components
The main components used in this project is:
1. Arduino Uno-R3
2. Ultra-Sonic Sensor (HC-SR04)
3. Power Supply
4. Temperature Sensor (LM35)
5. 16*2 LCD Display
6. Bluetooth Module (HC-05)
7. Current Sensor (ACS-712)
8. Voltage Sensor (B25)
9. Buzzer
10. DC Motor (Load)

2.2.1 Arduino Uno
Arduino Uno stands as a cornerstone in the realm of microcontroller development boards, renowned for its versatility, ease of use, and robust capabilities. Developed by Arduino LLC, the Arduino Uno has become synonymous with innovation in electronics prototyping and DIY projects, empowering enthusiasts, engineers, and students alike to bring their ideas to life.
At its core, Arduino Uno is powered by the ATmega328P microcontroller, featuring a straightforward interface and a rich ecosystem of libraries and community support. This combination makes it an ideal platform for a wide array of applications, spanning from simple blinking LED projects to sophisticated automation systems and IoT (Internet of Things) solutions

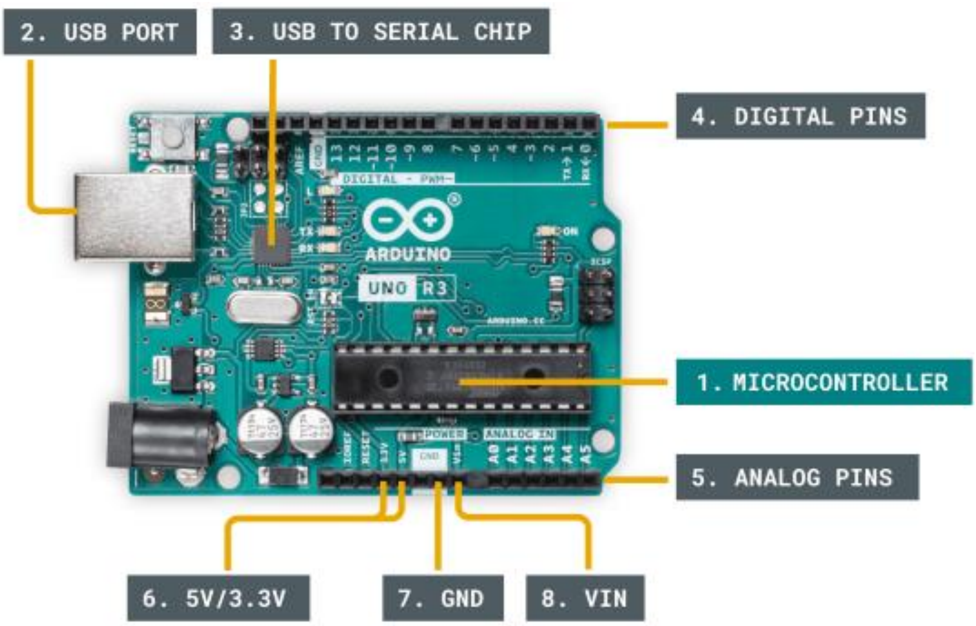

Fig. 2.1: Arduino Uno R3 pin description

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2.2.2 Ultrasonic Sensor

The HC-SR04 Ultrasonic Distance Sensor is a sensor used for detecting the distance to an object using sonar. The HC-SR04 uses non-contact ultrasound sonar to measure the distance to an object, and consists of two ultrasonic transmitters (basically speakers), a receiver, and a control circuit. The transmitters emit a high frequency ultrasonic sound, which bounce off any nearby solid objects, and the receiver listens for any return echo. That echo is then processed by the control circuit to calculate the time difference between the signal being transmitted and received. This time can subsequently be used, along with some clever math, to calculate the distance between the sensor and the reflecting object

Fig. 2.2: Ultrasonic Sensor

Ultrasonic Sensor Pin Configuration

1. Pin1 (Vcc): This pin provides a +5V power supply to the sensor.
2. Pin2 (Trigger): This is an input pin, used to initialize measurement by transmitting ultrasonic waves by keeping this pin high for 10us.
3. Pin3 (Echo): This is an output pin, which goes high for a specific time period and it will be equivalent to the duration of the time for the wave to return back to the sensor.
4. Pin4 (Ground): This is a GND pin used to connect to the GND of the system.

2.2.3 Power Supply

This is a simple approach to obtain a 12V and 5V DC power supply using a single circuit. The circuit uses two ICs 7812 and 7805 for obtaining the required voltages. The AC mains voltage will be stepped down by the transformer, rectified by bridge and filtered by capacitor to obtain a steady DC level. The 7812 regulates this voltage to obtain a steady 12V DC. The output of the IC1 will be regulated by the 7805 to obtain a steady 5V DC at its output. In this way both 12V and 5V DC are obtained.

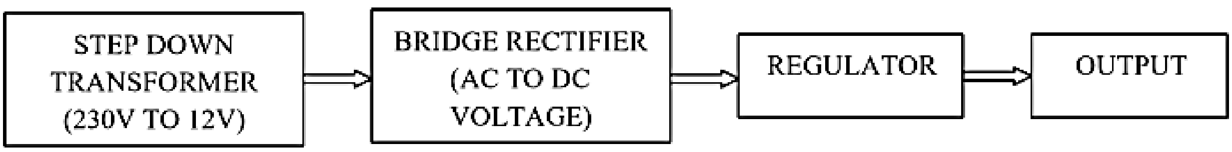

Fig. 2.3: Block Diagram of Power Supply

2.2.4 LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4 °C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface mount small-outline package and a plastic TO220 package.

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Fig. 2.4: Temperature Sensor

2.2.5 16*2 LCD Display

There are many display devices used by the hobbyists. LCD displays are one of the most sophisticated display devices used by them. Once you learn how to interface it, it will be the easiest and very reliable output device used by you! More, for micro controller-based project, not every time any debugger can be used. So, LCD displays can be used to test the outputs. LCD accepts two types of signals, one is data, and another is control. These signals are recognized by the LCD module from status of the RS pin. Now data can be read also from the LCD display, by pulling the R/W pin high. As soon as the E pin is pulsed, LCD display reads data at the falling edge of the pulse and executes it, same for the case of transmission. LCD display takes a time of 39-43µS to place a character or execute a command. Except for clearing display and to seek cursor to home position it takes 1.53ms to 1.64ms. Any attempt to send any data before this interval may lead to failure to read data or execution of the current data in some devices. Some devices compensate the speed by storing the incoming data to some temporary registers.

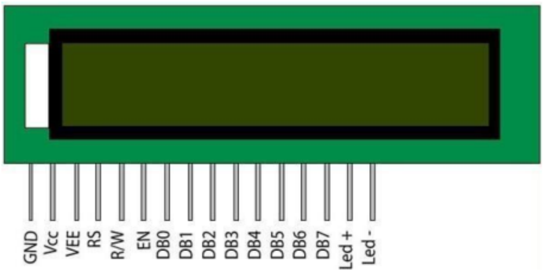

Fig. 2.5: LCD Display

2.2.6 HC-05 Bluetooth Module

The HC-05 is a Bluetooth module designed for wireless communication between microcontrollers and other Bluetooth-enabled devices. It operates on the 2.4 GHz frequency and supports Bluetooth Serial Port Profile (SPP), making it ideal for transmitting data over short distances. The module can work in both Master and Slave modes, allowing flexible communication with other Bluetooth devices. It uses UART (Universal Asynchronous Receiver-Transmitter) for communication, typically operating at a default baud rate of 9600. The key pin allows switching between AT command mode and data mode for configuration. The HC-05 operates at 3.3V logic levels but can be powered with 5V, making it compatible with Arduino and other microcontrollers.

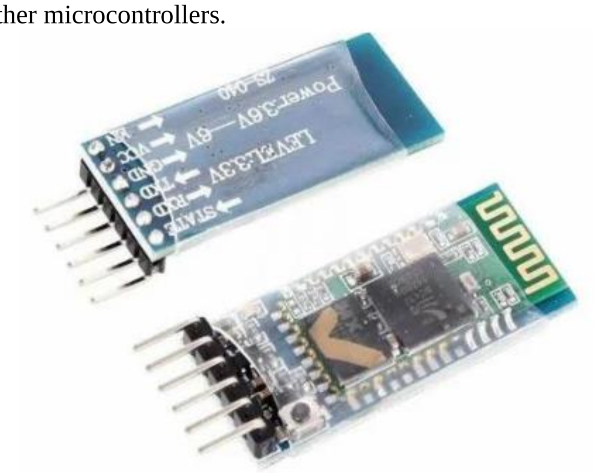

Fig. 2.6: Bluetooth module

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2.2.7 ACS-712 Current sensor

The ACS712 is a hall-effect-based current sensor that measures AC and DC currents with high accuracy. It is available in different variants (5A, 20A, 30A) based on the current range. The sensor provides an analog voltage output proportional to the detected current, making it easy to interface with Arduino or other microcontrollers.

Fig. 2.7: Current Sensor

2.2.8 B25 Voltage Sensor

The B25 Voltage Sensor is a simple voltage measurement module designed for use with Arduino and other microcontrollers. It is based on a voltage divider circuit using resistors to step down high input voltages to a safe level for analog measurement. This allows microcontrollers to measure voltages higher than their ADC (Analog-to-Digital Converter) limits.

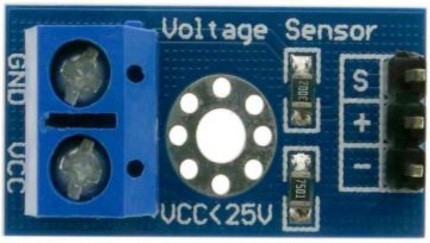

Fig. 2.8: Voltage Sensor

2.2.9 Buzzer

A buzzer is a simple yet effective electro-acoustic device designed to produce audible sound signals or alerts. It typically consists of an electromechanical transducer that converts electrical energy into mechanical vibrations, which in turn generate sound waves. Buzzer units come in various forms and sizes, ranging from small, compact versions used in electronic gadgets to larger, more robust versions employed in industrial equipment and alarms.

Fig:2.9 Buzzer

2.10 DC Motor

Motors rated for operation between 3 to 9 volts are versatile electromechanical devices designed to convert electrical energy into mechanical motion. They offer flexibility in voltage input, allowing adaptation to various power supply configurations while maintaining efficiency and performance.

Fig. 2.10 Motor

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3. EXPERIMENTAL PROCEDURE

3.1 Circuit Diagram

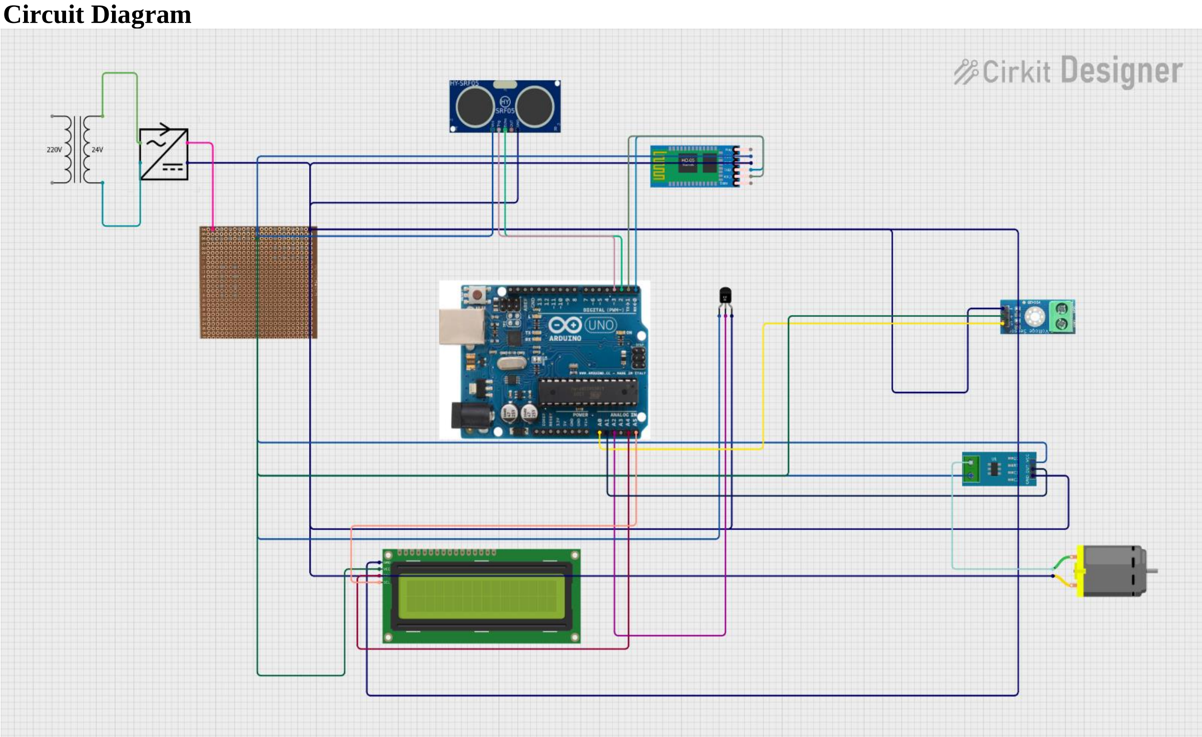

Fig. 3.1: Circuit Diagram

3.2 Connections

3.2.1 Ultrasonic Sensor (HC-SR04)

- Trig Pin: Connect to Arduino digital pin 2.
- Echo Pin: Connect to Arduino digital pin 3.
- VCC: Connect to 5V on the Arduino.
- GND: Connect to GND on the Arduino.

3.2.2 LM35 Temperature Sensor

- VCC (Pin 1): Connect to 5V on the Arduino.
- OUT (Pin 2): Connect to Arduino analog pin A2.
- GND (Pin 3): Connect to GND on the Arduino.

3.2.3 Voltage Sensor (Using Voltage Divider Circuit)

- Analog Output: Connect to Arduino analog pin A0.
- VCC: Connect to the positive terminal of the voltage source (via the voltage divider circuit).
- GND: Connect to the ground terminal of the voltage source.

3.2.4 Current Sensor

- VCC: Connect to 5V on the Arduino.
- OUT: Connect to Arduino analog pin A1.
- GND: Connect to GND on the Arduino.

3.2.5 16x2 LCD Display with i2C interface

- SDA: Connect to Arduino analog pin A4.
- SCL: Connect to Arduino analog pin A5.
- GND: Connect to GND on the Arduino.
- VCC: Connect to 5V on the Arduino.

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3.2.6 Bluetooth Module

- VCC: Connect to 5V on the Arduino
- GND: Connect to GND on the Arduino.
- TX: Connect to Arduino TX Pin 0
- RX: Connect to Arduino RX Pin 1

3.2.7 Buzzer

- VCC: Connect to Arduino digital pin 7
- GND: Connect to GND on the Arduino

3.3 Program Code

```
////Transformer Healthiness Monitoring System////
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>
// Set the LCD address to 0x27 for 16 chars and 2 line display
LiquidCrystal_I2C lcd(0x27, 16, 2);
// Define analog input
#define ANALOG_IN_PIN A0 // for volt sensor
const int sensorPin = A1; // for current sensor
// Floats for ADC voltage & Input voltage
float adc_voltage = 0.0;
float in_voltage = 0.0;
// Floats for resistor values in divider (in ohms)
float R1 = 30000.0;
float R2 = 7500.0;
// Float for Reference Voltage
float ref_voltage = 5.0;
// Integer for ADC value
int adc_value = 0;
// Define the maximum current the sensor can measure (in Amperes)
const float maxCurrent = 5.0;
int sensorValue;
float voltage;
float sensitivity = 0.100;
float actualCurrent;
const int trigPin = 2; // ultrasonic sensor
const int echoPin = 3;
int temp=0;
void setup()
{
// Setup Serial Monitor
Serial.begin(9600);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
pinMode(A0, INPUT);
pinMode(A1, INPUT);
pinMode(A2, INPUT);
pinMode(7, OUTPUT);
lcd.begin();
// Turn on the blacklight and print a message.
lcd.backlight();
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
lcd.print("Transform Health");//print name
lcd.setCursor(0, 1); // set the cursor to column 0, line 2
lcd.print("Monitor System");//print name
Serial.println("Transform Health Monitoring System ");
delay(2000);
lcd.clear();
}
void loop()
{
temp = analogRead(A2);
temp = temp * 0.48828125;
adc_value = analogRead(ANALOG_IN_PIN); // Read the Analog Input
adc_voltage = (adc_value * ref_voltage) / 1024.0; // Determine voltage at ADC input
in_voltage = adc_voltage*(R1+R2)/R2; // Calculate voltage at divider input
sensorValue = analogRead(sensorPin);
voltage = sensorValue * (5.0 / 1023.0); // Convert the sensor value to voltage (assuming a 5V reference voltage)
actualCurrent = voltage / sensitivity; // Calculate actual current based on maximum current
lcd.clear();
```

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```
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
lcd.print("V = ");//print name
lcd.setCursor(3, 0);
lcd.print(in_voltage);
lcd.setCursor(9,0);
lcd.print("volts");
lcd.setCursor(0, 1); // set the cursor to column 0, line 2
lcd.print("I = ");//print name
lcd.setCursor(3, 1);
lcd.print(actualCurrent);
lcd.setCursor(9, 1);
lcd.print("mA");
Serial.print("Voltalge = ");
Serial.print(in_voltage);
Serial.println("Volts");
Serial.print("Current = ");
Serial.print(actualCurrent);
Serial.println("mA");
delay(2000);
lcd.clear();
digitalWrite(trigPin, LOW); // Trigger the ultrasonic sensor
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
long duration = pulseIn(echoPin, HIGH); // Measure the time taken for the sound wave to return
float distance_cm = duration * 0.034 / 2; // // Calculate the distance in centimeters
lcd.clear();
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
lcd.print("Oil = ");//print name
lcd.setCursor(6, 0); // set the cursor to column 0, line 2
lcd.print(distance_cm);//print name
lcd.setCursor(11, 0); // set the cursor to column 0, line 2
lcd.print("cm");//print name
lcd.setCursor(0, 1); // set the cursor to column 0, line 2
lcd.print("Temp = ");//print name
lcd.setCursor(7, 1); // set the cursor to column 0, line 2
lcd.print(temp);//print name
lcd.setCursor(11, 1); // set the cursor to column 0, line 2
lcd.print("C");//print name
Serial.print("Temperature = ");
Serial.print(temp);
Serial.println("C");
Serial.print("Oil Distance: ");
Serial.print(distance_cm);
Serial.println(" cm");
delay(1000);
if(temp>45)
{
lcd.clear();
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
lcd.print("Temperature");//print name
lcd.setCursor(0, 1); // set the cursor to column 0, line 2
lcd.print(" is High");//print name
Serial.println("Temperature is HIGH");
digitalWrite(7,HIGH);
delay(2000);
digitalWrite(7,LOW);
lcd.clear();
}
if(distance_cm>3)
{
lcd.clear();
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
lcd.print("Oil is LOW");//print name
Serial.println("Oil is LOW");
digitalWrite(7,HIGH);
delay(2000);
digitalWrite(7,LOW);
lcd.clear();
}
}
```

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3.4 Block Diagram

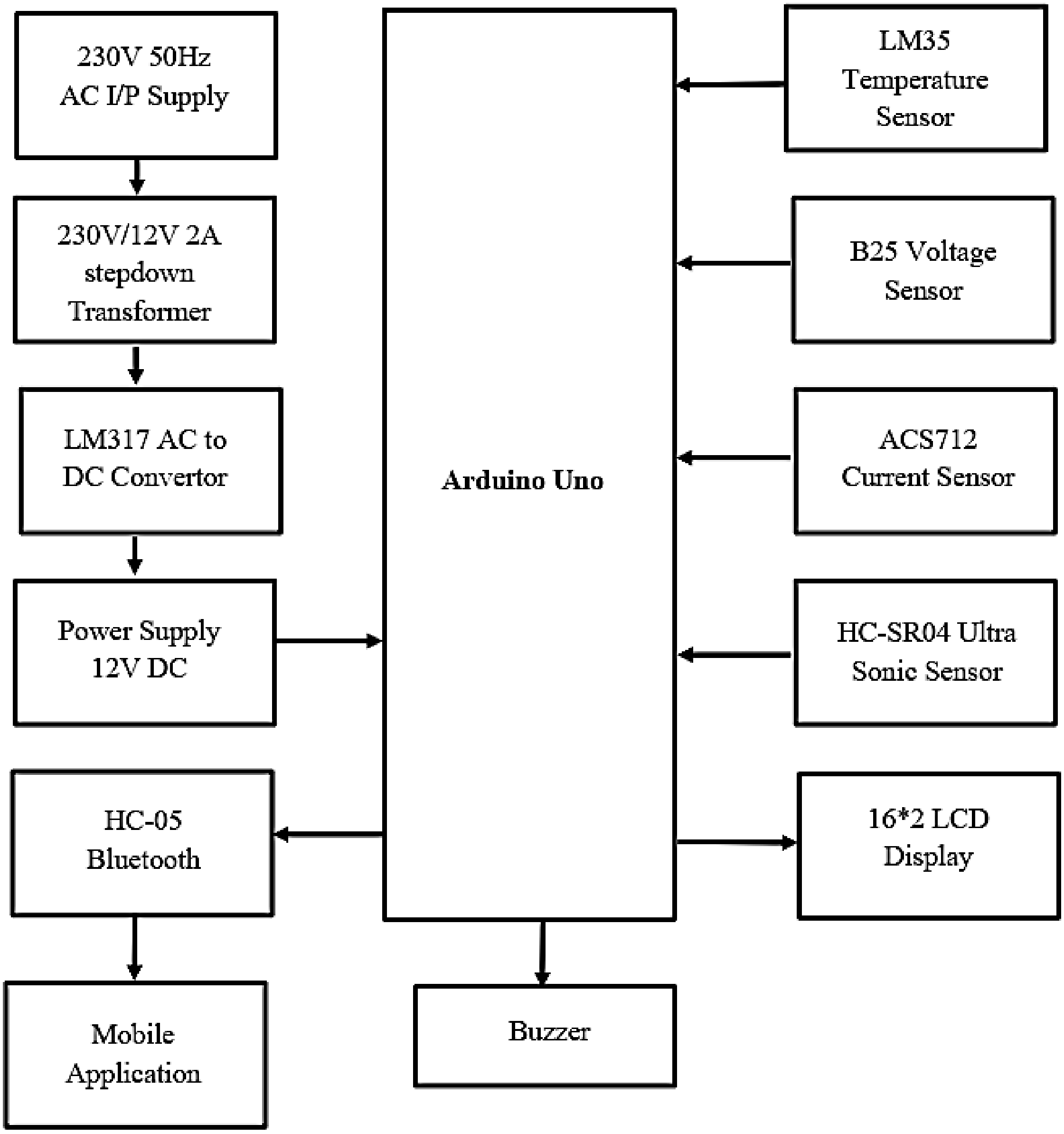

Fig 3.2: Block Diagram

4. RESULTS AND DISCUSSIONS

4.1 Fault No.1

Temperature Ambient temperature of Transformer is high or it will be increase it sense through the sensor LM-35 and gives alert. Through buzzer and automatically cooling will be turn on.

4.2 Fault No.2- Oil Level

In this system in transformer oil level is low or high it senses the by using ultrasonic sensor it gives the alert through buzzer.

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4.3 Hardware Output Images

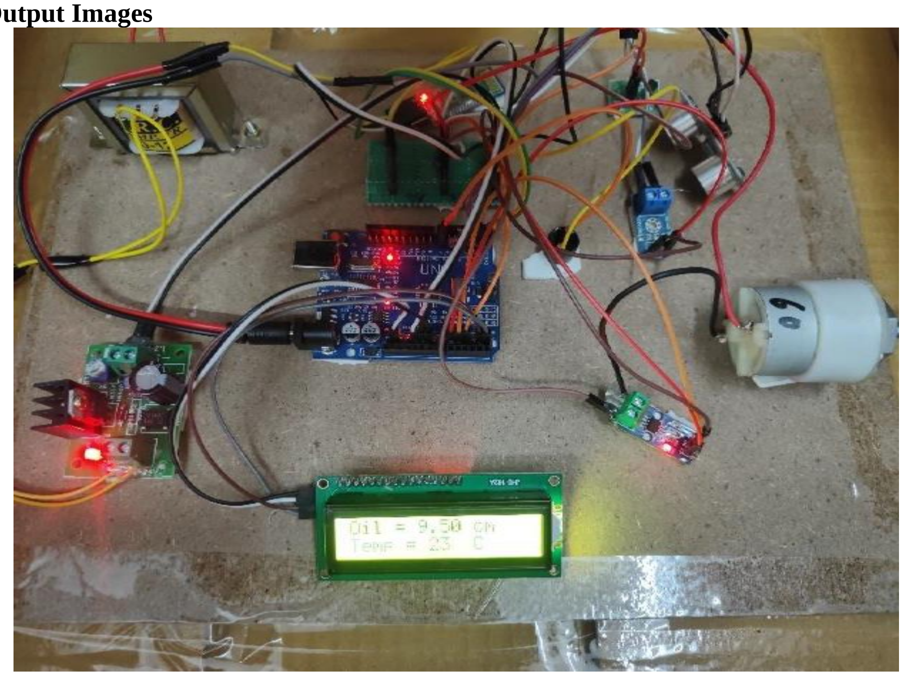

Fig. 4.1: Hardware output 1

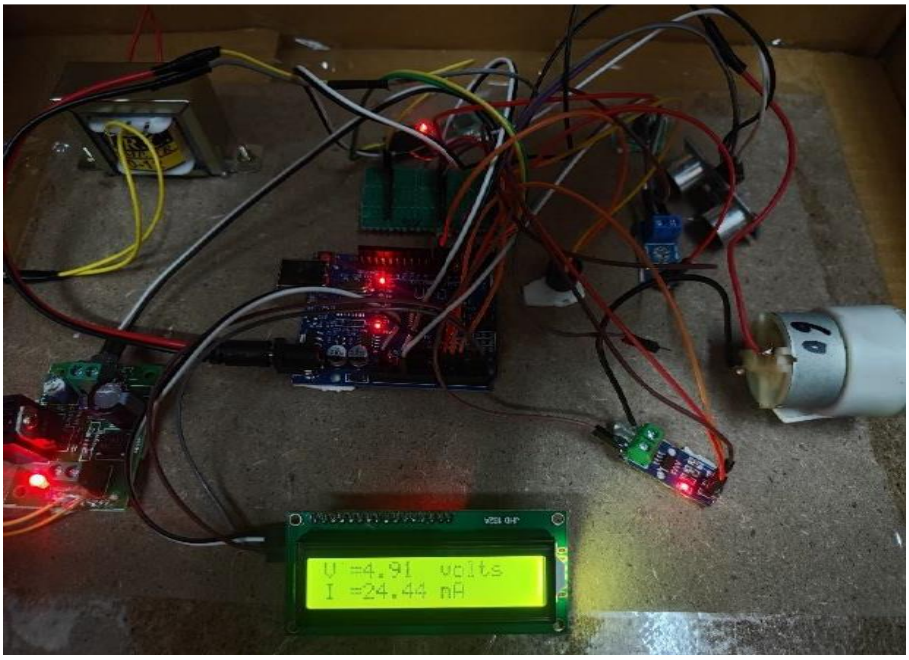

Fig. 4.2: Hardware output 2

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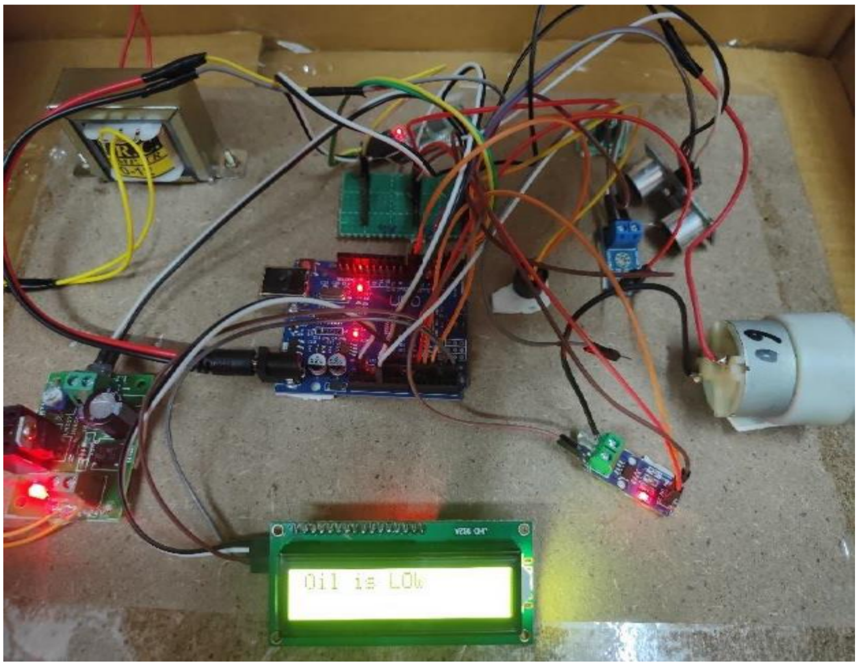

Fig. 4.3: Hardware output 3

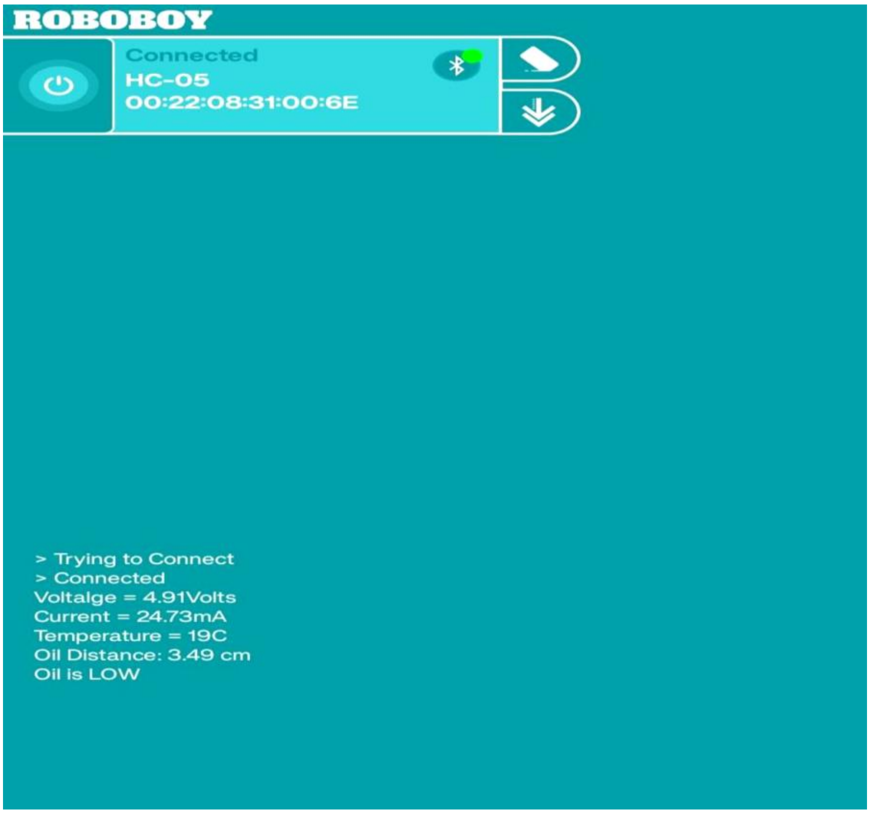

Fig. 4.4: Hardware output 4

4.4 Advantages of Transformer Healthiness Monitoring System

1. Early Fault Detection:

• Identifies issues such as overheating, oil depletion, and electrical imbalances before they lead to major failures.

2. Predictive Maintenance:

• Reduces maintenance costs by enabling condition-based servicing instead of expensive reactive repairs.

3. Remote Monitoring:
• Allows engineers to track transformer health in real-time via Bluetooth, minimizing the need for on-site inspections.
4. Enhanced Reliability:
• Ensures stable power distribution by preventing unexpected transformer failures.
5. Increased Safety:
• Reduces risks of hazards like electrical fires, explosions, and power outages.
6. Extended Transformer Lifespan:
• Continuous monitoring helps maintain optimal performance, prolonging the transformer's operational life.
7. Improved Operational Efficiency:
• Enables quick decision-making and corrective actions, reducing downtime**.**

4.5 Disadvantages of Transformer Healthiness Monitoring System
1. Limited Wireless Range:
• Bluetooth-based monitoring restricts remote access beyond a certain distance.
2. Initial Implementation Cost:
• Installing sensors and integrating the system may require an upfront investment..
3. Data Security Concerns:
• Wireless data transmission may be vulnerable to interference or cyber threats if not properly secured.

4.6 Future Scope

- AI and Machine Learning: Implementing AI-based predictive analytics to forecast failures based on historical trends.
- Extended Communication Range: Using Wi-Fi, LoRa, or GSM for long-distance remote monitoring.
- Automated Control Systems: Developing self-regulating mechanisms that adjust transformer parameters based on real-time conditions.
- Integration with Smart Grids: Enhancing power grid resilience by linking transformer data with smart grid infrastructure.
- Solar-Powered Monitoring**:** Implementing energy-efficient power sources to sustain monitoring systems in remote areas.

5. CONCLUSIONS

The proposed Transformer Health Monitoring system has shown promising results, with high accuracy and sensitivity in detecting abnormal and faulty conditions. This system provides a reliable protection scheme for transformers, ensuring that any potential issues are identified before they lead to serious failures. By continuously monitoring critical parameters such as oil level, temperature, voltage, and current, the system is capable of providing early warnings about the transformer's health, allowing for proactive maintenance and preventing unplanned outages.

The integration of IoT and cloud technologies enhances the system's functionality, enabling remote monitoring from anywhere, eliminating the need for on-site human intervention. This not only improves the efficiency of maintenance processes but also ensures that the status of the transformer is constantly updated in real-time, making it easy to track any abnormal conditions. In the event of an issue, the system automatically updates the cloud, ensuring that the relevant stakeholders are promptly notified.

By identifying faults and abnormal conditions early, the system significantly reduces downtime, increases the lifespan of transformers, and results in substantial cost savings in terms of repairs and replacements. This automated approach enhances the reliability of the transformer, reduces human error, and ultimately optimizes the performance and maintenance of the electrical infrastructure. Therefore, the Transformer Health Monitoring system provides a comprehensive solution for continuous, efficient, and cost-effective transformer management.

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