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Development of Dissolved Gas Analyser for Transformer Oil Using Nano Gas Sensor and Arduino

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ABSTRACT

This paper proposes a new type of dissolved gas analyzer by which we can do online monitoring of gases dissolved in the transformer oil. In the proposed technique a nano gas sensor is installed within the transformer conservator and is interfaced with the arduino microcontroller by which the gas type, its concentration and operating temperature is displayed on LCD screen of arduino board. To check the reliability of the proposed technique it has been tested on transformer oil containing hydrogen and methane.

Keywords: Power transformer protection**,** Semiconductor metal oxide (SMO), Gas sensor, sensitivity, surface reaction, nano technology, arduino, thermocouple.

1. INTRODUCTION

Now-a-days, the protection of any power system network is the most important task for any distribution, transmission and generation unit. Several types of faults occur on the power system network on regular basis. Oil filled transformers are one of the key equipment of power systems. So its control and monitoring is very important for its effective operation. Whenever any fault occurs in transformer different types of gases such as ethane, methane, hydrogen, acetylene, carbon mono oxide etc. are produced based upon the type of fault. These gases get dissolved in the transformer oil and decreases it breakdown strength. Dissolved gas analysis for detection of the gases in transformer oil is an old fashion, now we are using gas sensor based on nano technology [1-3].

This paper provides the new type of dissolved gas analyzer by which online monitoring of gases dissolved in the oil can be done.

1.1. Discussion on gas sensor and transformer oil

Now-a-days semi-conductor metal oxide gas sensor interfaced with arduino is used to know the concentration of different gasses dissolved in power transformer (The key gases with the probable faults are presented in table I).

Here, a zinc oxide based nano gas sensor is interfaced with the arduino micro controller bywhich the concentration of gases dissolved in the oil at different operating temperatures is determined. The sensitivity of zinc oxide is different for different gases at different operating temperature [4-5].

Most of the faults which occur in the transformer contain hydrogen gas [6-8]. SMOs are used in these gas sensors with the help of nano technology are used for detection purpose.

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During the past few decades the SMO gas sensor are primarily used because of their low cost, reduced size, and easy measurement.

Table 1
Gases present in a transformer corresponding to the probable faults.

Key Gases	*General Fault Condition*
Methane, Ethane, Ethylene	Thermal condition involving the oil
Hydrogen., Methane and Ethane	Partial discharge
Hydrogen , Acytlene , Ethylene	Arcing
Carbon dioxide ,Carbon monoxide	Thermal condition involving the paper

1.2. Discussion on arduino

Arduino microcontroller is an open source electronics platform based on easy to use hardware and software. It is of major help for anyone interested in making interactive projects. It is an easy to use yet powerful single board computer that has gained considerable usage in the professional market. Arduino programming language is a simplified version of C/C++.

An important feature of the arduino is that it can be used to control a program on the host PC, it is downloaded to the Arduino and it runs automatically. The USB cable connection to the PC can be removed and the program will still run from the top each time the reset button is pushed. It means that the board can be connected to the host PC to develop and debug the program but once that is done, PC is no longer required to run the program again.

Requirements for Arduino Working System:

These are the requirements of arduino working environment:

1. Arduino Duemilanove board
2. USB programming cable (A to B)
3. 9V Battery or external power supply (for standalone operations)
4. Solderless bread board for external circuits
5. Host PC running the Arduino development environment versions exist for windows etc.

2. METHOD OF DETECTION OF GASES

There are mainly two methods for the detection of dissolved gases present in oil of power transformer

1. Dissolved gas analysis by gas chromatography.
2. Measurement through gas sensors.

In *Gas Chromatography*method, Firstly the supply to the power transformer is shut down and gas sample is extracted from the oil and then analysed using various chemical reactions.

While in*Gas Sensor*method various sensors such as metal oxide based gas sensor, capacitance based gas sensor, and optical gas sensor, etc. are installed within the conservator tank which analyses the gas present in the oil using the phenomenon of surface reaction in with nano material. Hence there is no need to interrupt the supply.

Here metal oxide based gas sensor has been used.

3. METAL OXIDE BASED NANO GAS SENSORS

Metal oxide sensors are also known as chemiresistors. The detection principle of these resistive sensors is based on change of the resistanceof a thin film upon adsorption of the gas molecules on the surface of a semiconductor In this paper zinc oxide based nanogas sensors are being used.In the field of gas sensors, there are various metal oxide semiconductors like SnO, TiO_3, ZnO etc but the most used metal oxide is ZnOwhich is used in the fabrication of the nano gas sensors.

The operating principle of these SMO gas sensors is based on the phenomenon that the electricalconductivity of a semiconducting metal oxide varies with thecomposition and the concentration of the gas atmosphere surrounding it.

Gases detected using ZnO based gas sensors-: NH_3, H_2, CO, NH_3, CH_4, and ethanol vapours.

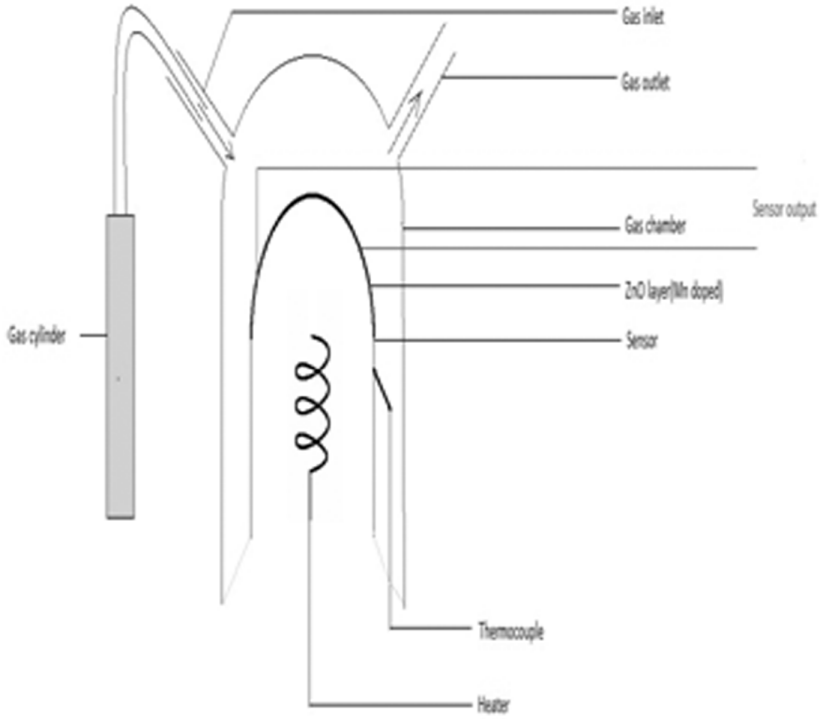


Figure 1: Nano Gas Sensor

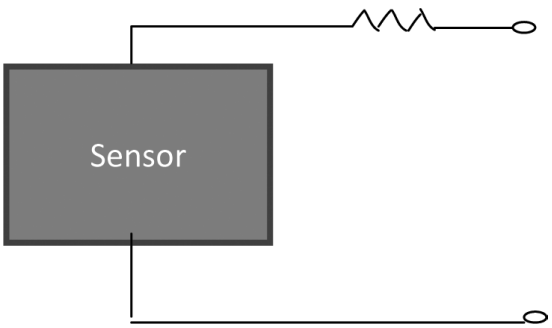


Figure 2: Basic block diagram of sensor

4. EXPERIMENTAL SETUP

4.1. Gas sensing mechanism

When a ZnO based gas sensor is exposed to air then oxygen will be absorbed on the surface of ZnO layer and form an O^{-2}, O^{-} or O^{2-} ion by capturing electrons from the ZnO conduction band.

That is, by releasing electrons back into the ZnO conduction band and increasing the carrier concentration in the ZnO active layer, sensor's resistance is decreased upon exposure to any reducing gas such as NH_3, CH_4, H_2, etc.

$$2NH_3 + 3O^- 3H_2O + N_2 + 3e^-.$$

The gas sensitivity (S), for a reducing gas was determined by using the ratio of the change in conductance upon exposure to the target gas in dry air to the conductance in dry air.

Sensitivity of sensor = Ra/Rg

Where,

Ra : resistance of gas sensor when exposed to the dry air only

Rg : resistance of gas sensor when exposed to the target gas in dry air.

In this experiment the voltage across the sensor IS measured and then sensitivity is calculated as:

Sensitivity = Vg /Va

Here,

Va = voltage across the sensor when exposed to dry air.

Vg = voltage across the sensor when exposed to target gas.

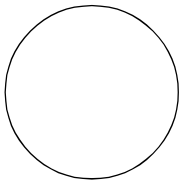


Figure 3: Experimental setup for Gas Sensing

4.2. Interfacing with arduino

In the proposed method ZnO based gas sensor is installed within the transformer conservator and is interfaced with the arduino microcontroller by which the gas type, its concentration and operating temperature is displayed on LCD screen of arduino board.

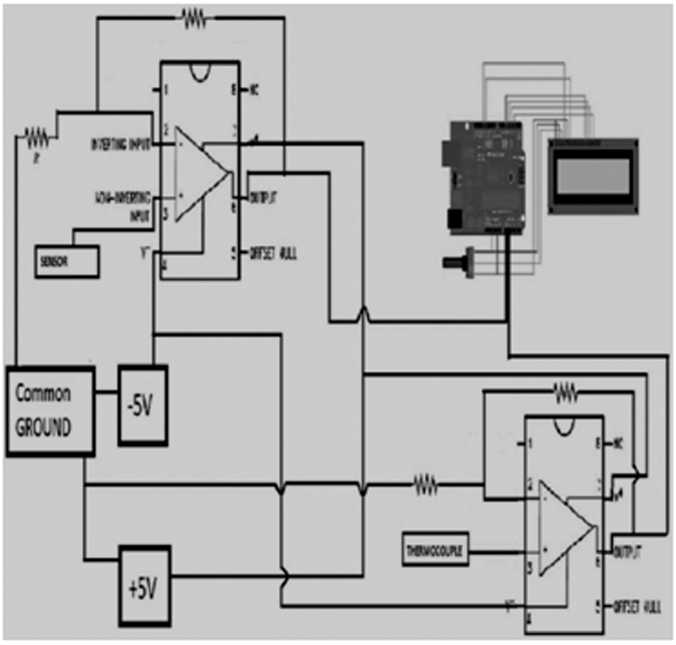


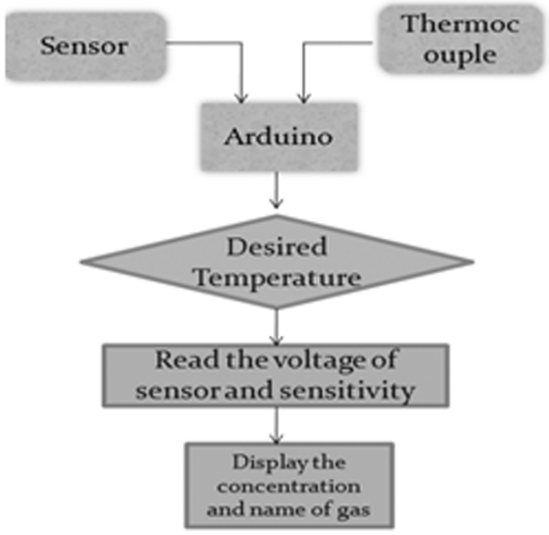
Figure 4: Sensor interfaced with Arduino

5. COMPUTATIONAL PROCEDURE

In this technique, a modern gas sensor is designed using which firstly the voltage of the gas sensor is calculated and then it is compared with the voltage of J TYPE thermocouple with the help of op-amp microcontroller and mathematical equations the concentration of different gases present in the transformer oil can be calculated.

By knowing the concentration of these gases, the health of transformers may be assessed, aging of transformer oil can be detected; also the type and intensity of fault can be identified so that early detection can be done to minimize the outages of transformers.

A flowchart representing the above procedure is givenbelow:



6. MATHEMATICAL RELATION BETWEEN SENSITIVITY AND CONCENTRATION

Using the standard experimental data of the sensor developed in CMERI the relation between sensitivity and concentration was determined using matlab (cftool command) from the graphs given below

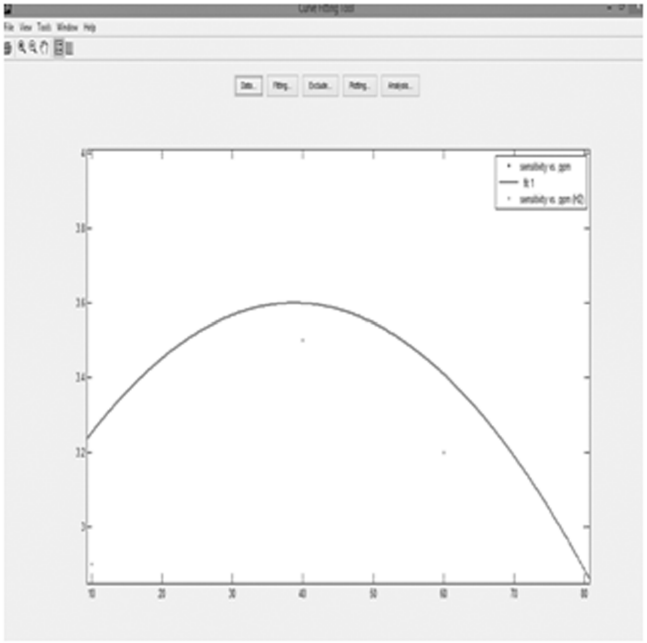


Figure 6:Sensitivity Vs PPM (H_2)

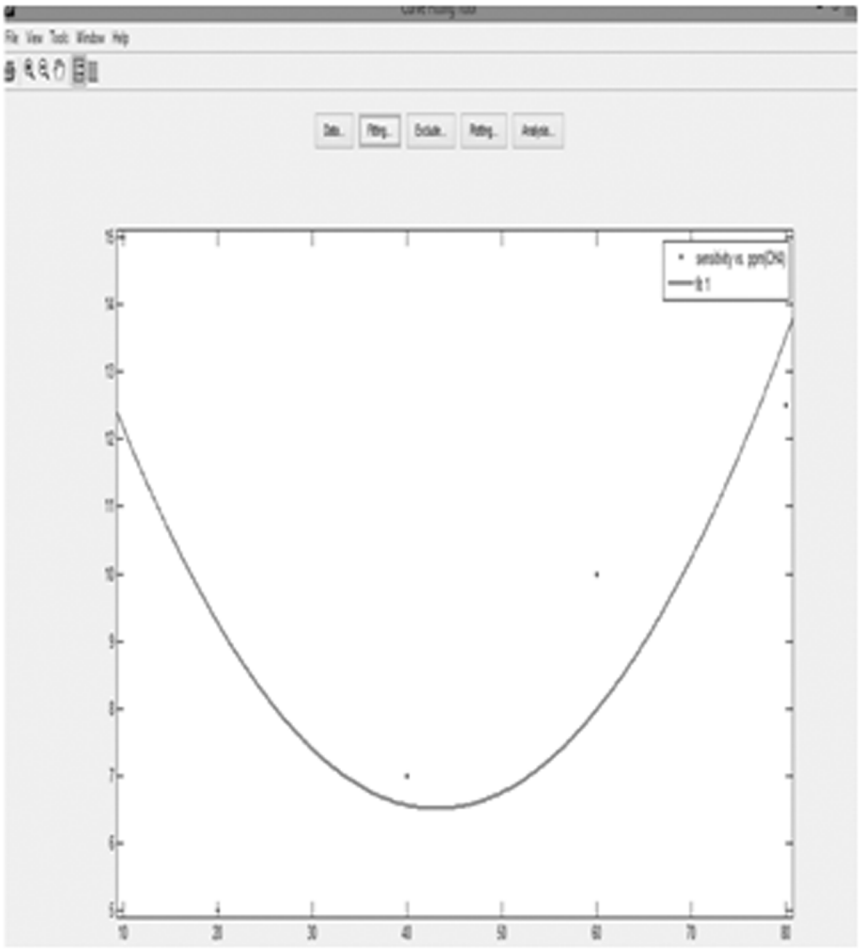


Figure 7: Sensitivity Vs PPM (CH_4)

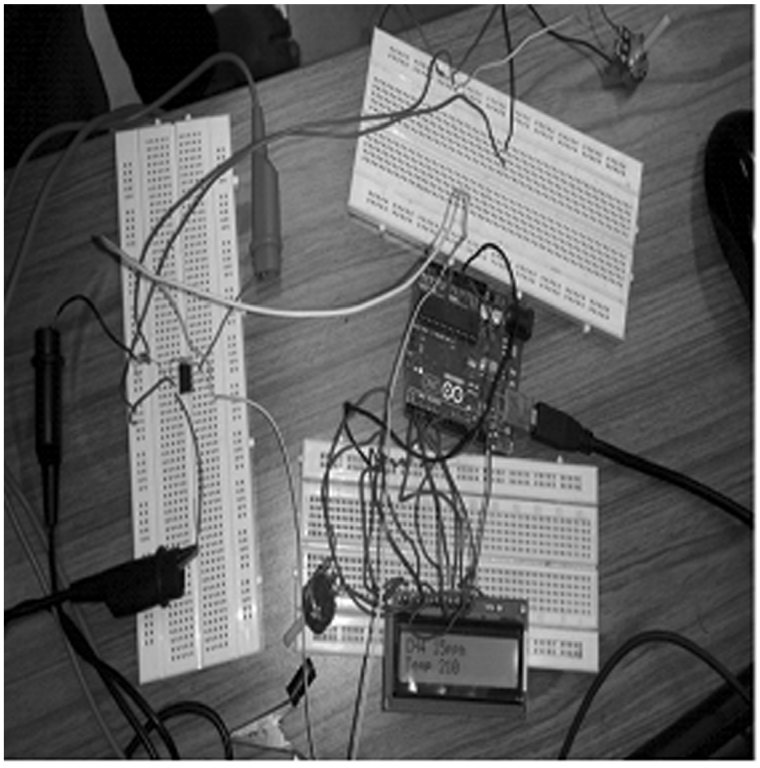


Figure 8: Experimental Setup for Arduino interfacing

Mathematically,

$$C = P1 * S2 + P2 * S + P3$$

Where,

P1, P2, P3 are constant for different gases.

GAS	CONSTANT VALUES
For H_2	P1 = -0.0004193 P2 = 0.3249 P3 = 2.97
For CH_4	P1 = 0.005168 P2 = 0.4457 P3 = 16.12

7. ARDUINO AND SENSOR LIMITATIONS

There are fewlimitations related with measurement using Arduino Uno. Precision of arduino is very poor, for example when the output voltage of op- amp is 1volt then the digital value shown is 725 but if we run the arduino then it changes by ± 10.so every time it gives different readings while reading analog value.

Other limitation of arduino is that itdisplays the same values for input voltages differing in decimal. So the gases in which temperature difference is very less for the maximum sensitivity, arduino is not able to display the right gas and its concentration. This limitation is shown in table II

The above discussed limitations can be removed by using arduino mega version by increasing the selectivity of sensor. Here A/D convertoris used, which is assembled with the arduino board so that that there is difference in digital values. So an A/D convertor has to be designed as per our requirement

Table 2
Arduino Limitation

Input VOLTAGE	*OP-AMP Output*	*ARDUINO O/P*	*Temp*
9.7 mV	1.067	1V	172
10.1 mV	1.111	1V	178
11 mV	1.21	1V	195
12.1mV	1.331	1V	210
12.3 mV	1.353	1V	218
14 mV	1.54	2V	249
15.8 mV	1.738	2V	282

8. RESULT

The result shows in the table form given below. Here we are calculating the concentration and operating temperature of two gases given below:

Table 3
Output Table

Gas	*Conc(ppm)*	*Temp*	*sensitivity*	*original ppm*	*i/p(in mV)*	*o/p(in V)*	*Error*
CH_4	16	210	7.2	28	12.3	2	40%
H_2	2.97	190	1.13	5	10.1	1	40%

9. CONCLUSION

From the above discussion it can be said that the above gas analyzer can be used for online monitoring of power transformer without interrupting the supply. The concentration and operating temperature can be monitored on daily basis so that the power transformer can work properly. The sensor has fast response and recovery time, which is a characteristic of a good sensor. By interfacing the nano gas sensor with arduino, information about the gases can be easily obtained visually. Its small size is helpful and it will bring new revolution in the field of protection and gas analyzer.

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