IMAGE PROCESSING BASED ANALYSIS OF TRANSFORMER OIL

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IMAGE PROCESSING BASED ANALYSIS OF TRANSFORMER OIL

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering

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CERTIFICATE

This is to certify that the thesis entitled**, “Image Processing Based Analysis of Transformer Oil**” submitted by **Mr. Ashis Ranjan Gouda, Roll No. 110EE0124,** in partial fulfilment of the requirement for the award of Bachelor of Technology Degree in Electrical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Transformer oil is a mixture of hydrocarbons which can tolerate high temperature and is an excellent insulator. This not only serves as insulator but also as a coolant. Besides this suppresses sparking, arching and corona. Oil degrades because of gases dissolved in it due to the occurrence of various faults and deterioration with respect to age. Increase in dissolved fault gases concentration in oil, results in oil losing its effectiveness; this will influence the transformer performance. Hence, to prevent the transformer failure, oil analysis is very essential and there are several methods to diagnose the health of the oil. Various tests like Dissolved Gas Analysis (DGA), Electrical Diagnostics etc. can evaluate the transformer health but this method is very vast, dangerous during oil transaction and lengthy. Image processing based analysis is a quick software based analysis which inputs images of transformer oil, processes it based on suitable image processing techniques and determines the prominent characteristic features of transformer oil i.e. acidity, power factor, NN (Neutralization Number), dissipation factor etc. due to ageing color of transformer oil changes and also these factors also deteriorated. These factors and transformer oil color are very closely interrelated. In this project it is the interrelation between these two are found out by using entropy method and linear regression technique. Also the presence of different gases like H_2,C_2H_6,C_2H_4,C_2H_2,CH_4, CO_2, CO, O_2, N_2 etc. are very important to be detected in order to detect the kind of fault occurred and about transformer history. Thus in this project the presence of oil in ppm level is detected using linear regression method. Also by using the quantity of these gases the kind of fault in transformer is found out using two methods: key gas method and iec method and GUI models are built for easy graphical interface.

KEY WORDS: Entropy; NN; Acidity; Power factor; Dissipation factor; corona; DGA

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Chapter 1

Introduction

Electrical energy plays an important role in a nation's development. A reliable and proficient power system is needed to meet large demand for electricity. Transformer is an integral part of power system whose role is critical for a reliable power system. Periodically the health of transformer has to be checked which primarily depends on the type of insulation used. Out of different insulators used in transformer, mineral oil so as to say transformer oil is used as an insulation material in almost all transformers. Transformer oil not is only used for insulation purpose, but also for cooling purpose. Its dielectric strength, different chemical properties determine the type of insulator it is which in turn determines the health state of a transformer. Thus its performance mainly depends on characteristics of mineral oil used. Thus it is very important to perform oil analysis periodically to check transformer health. There are a number of traditional methods available. But these methods are very time consuming and expensive. This paper provides a quick simple method to analyze transformer oil and thus to check transformer health from the image of a transformer oil sample. The image processing technique involves preprocessing of the taken image of transformer oil in which first the noises are removed using median and weinner2 filter and histogram enhancement technique is used for better visibility. Now entropy which is the statistical measure of randomness is calculated which depends mainly on the deterioration of the taken oil sample. Thus using regression method from the knowledge of entropy and learned data the state properties of oil can be predicted. Similarly the concentration of gases present in transformer oil can be calculated. This project also provides a tool to predict for the different faults in the transformer using key gas analysis method and iec basic ration method.

Chapter 2

Background and Literature Review

2.1 CHEMICAL METHODS USED FOR TRANSFORMER OIL ANALYSIS

2.1.1 Dissolved Gas-in-Oil Analysis [9]

The main causes of transformer insulation break down are thermal and electrical disturbances. There are mainly two types of insulation [3] paper insulation which consists of cellulose and oil which is a mixture of hydrocarbons. Due to excessive thermal and electrical stress cellulose and hydrocarbon undergoes various chemical reaction to form different gases as byproduct. These gases are hydrogen(H_2), ethane(C_2H_6),methane (CH_4),ethane (C_2H_4), ethyne (C_2H_2), nitrogen dioxide (NO_2), carbon dioxide(CO_2), carbon monoxide(CO). In Dissolved Gas-in-Oil Analysis (DGA) method these gases are analyzed quantitatively to infer existence of any fault mainly incipient faults[7].

2.1.2 Electrical Diagnostics[4]

The common electrical diagnostics tests are briefly described as follows:

2.1.2.1 Winding Power Factor:

Due to thermal and electrical stress windings are deformed (e.g. buckling of transformer winding), insulation get deteriorated etc. This results into increase in the power loss in insulations and thus the winding power factor varies. Thus winding power factor is a parameter for diagnostics of transformer oil.

2.1.2.2 Bushing Power Factor:

Bushings provide insulations to electrically separate conductors from transformer tank. Bushing insulations also get deteriorated due to thermal and electrical stress and thus bushing power factor has been used over years to save transformers from faults by detection of bushing power factor.

2.1.2.3 Leakage Reactance:

In adverse cases the coil displaces from their original position and this causes a change in the flux linked and there is a change in the leakage reactance. Thus leakage reactance is taken into consideration in diagnosing the transformer oil analysis.

2.1.2.4 Transformer Turns Ratio:

Transformer turns ratio gets changed when there is a short circuit of windings and thus TTR is included in the diagnostics of transformer oil.

2.1.2.5 DC Winding Resistance:

Due weak contact of windings, weak joints and short circuit of winding the dc resistance of the winding get changed. Thus dc winding resistance is a required oil diagnostic tool.

2.1.2.6 Core Excitation Current

Core excitation current is the current which is required to excite the core of transformer changes with core deformation, core damage and winding shorting. Thus this factor also added in diagnostics of transformer oil.

2.1.2.7 Core Ground:

Grounding of core results into circulating current and which leads to overheating thus where core ground is accessible this test should be performed.

2.1.2.8 Sweep Frequency Response Analysis (SFRA):

In this test a signal with varying frequency is injected into the transformer coil and the output response is analysed numerically and FFTs are used to detect any core/coil anomalies. Deformation of coil, damage of core, winding short circuiting can be detected in this method.

2.1.2.9 Additional Tests

Besides the above test there are some other tests like thermography, partial discharge vibration analysis etc. can be included in diagnostics of transformer oil.

2.2 USEFUL TRANSFORMER OIL PROPERTY DETERMINATION [1]

Acidity and tanδ are the most important properties of the oil. It indicates whether the quality of the oil has deteriorated or not. Acidity can be defined as the amount in mg. of KOH (Potassium Hydroxide) required to neutralize 1 gm of oil sample. The amount of Acidic or alkaline material present in oil is measured from Neutralization Number (NN). As oil gets aged, acidity increases therefore NN also increases. If oil NN is high, that indicates oil is more contaminated with materials, such as varnish foreign matter or oxidization.

Usually there is no acid content in new oil, oxidation of insulation forms the sludge's and impulse out of transformer metal in side tank forms the soaps from acid assault and also increase the insulation degradation.

NN is definite relation with Interfacial Tension (IFT). Interfacial Tension indicates the tension at interface between two non-mixing liquids. Solid insulation material produces the dissoluble polar contaminants and oil decompose product. Lower IFT indicates that oxidation products present on oil.

To determine the acidity of oil, potentiometric titration with potassium hydroxide is used and for tanδ measurement Schering Bridge is utilized.

These conventional diagnostic methods are devouring much time to estimate the oil properties. To overcome the disadvantages of traditional method, an image processing technique of Entropy method is proposed in this work.

2.3 ENTROPY TECHNIQUE FOR OIL PROPERTY DETERMINATION [1]

As oil gets aged color and texture of the oil changes, at the same time some of the properties related to oil also change. In this work Acidity and tanδ of oil is calculated from image processing approach called Entropy. Entropy can be described from equation (1)

$$\sum a \log_2 a \quad \ldots\ldots(1)$$

Where 'a' contains the histogram counts

Entropy measures the randomness statistically. Entropy accounts for indicating the texture of an input image. Acidity calculation is done on the basis of straight line formula, because when the samples Ageing v/s Acidity graph is drawn, a slope exists.

The NN values can be estimated from equation (2)

$$NN = A_c y + c \quad \ldots\ldots(2)$$

Where, NN = Neutralization Number; c = constant = 0.013; y = years Ac = Acid constant

Acid constant value can be obtained from equation (3)

$$Ac = \frac{F_{nn} - I_{nn}}{T_y} \quad \ldots\ldots(3)$$

Where, Fnn = Final neutralization number from standard test Inn = Initial neutralization number from standard test

Ty = Total number of years Ac = {0.013 0 ≤ Ty ≥ 14, 0.0159 15 ≤ Ty ≥ 25}

Two Ac values are taken to acquire the NN, the reason behind this is that the acidity is not constantly enhancing.

tanδ or Dissipation factor can be calculated from equation (4)

$tan\delta = yk$……………………………………………………….……...…..(4)

Where,

$y \neq 0$ (fresh oil ageing is taken as 1)

k = constant

$k = \{0.0021 \quad 0 \leq Ty \geq 14$

$\{0.00719 \quad 15 \leq Ty \geq 25$

Power factor of the oil can be calculated from equation (5)

$$powerfactor = \sqrt{\frac{\tan^2\delta}{1+\tan^2\delta}} \quad \text{……………………………………...….……..…..(5)}$$

To acquire both NN and tanδ of transformer oil, ageing year of oil is essential. Equation (6) is used to calculate y value from Entropy of the image

$$y = (E1 - E0) / k1 \text{ ………………………………………………………….(6)}$$

E_0= Entropy of the fresh oil

E_1 = Entropy of the oil sample (old)

k_1 = 0.046

2.3.1 ALGORITHM

Evaluation of NN and tanδ of Transformer oil by Entropy method

1 .Load the image

2. To remove noise use median and weinner2 filters.

3. Enhance the image using histogram modification technique.

4. Find the Entropy (E).

5. Declare k_1 and determine y

6. Check for $y \geq 14$

7. If y is less than 14 years, set Ac = 0.013 for NN and set $k_2 = 0.0021$ for $\tan\delta$ calculations

8. If $15<y<25$, set Ac=0.0159 and k_2 =0.00716 to compute $\tan\delta$ and acidity.

9. If y >25, result will show error

Ghoneim,S.S.M., [10] studied about transformer faults and suggested that, sudden increase of gas concentration indicates an impending trouble within the transformer. The DGA test suggests that analyzing another sample and compares the new sample evaluation with previous one will determine the key gas concentration.

Sharma,N,K., [2] describes how an Artificial Neural Network method is used as an application in DGA to increase the computational efficiency. There is a hidden relationship between dissolved gases and fault types; this can be very effectively recognized from the ANN method through training process. Back propagation algorithm is adopted in the ANN method to diagnose faults in the transformer.

Chapter 3

Methodology

This paper describes about the how transformer oil is analyzed from an image of transformer oil. The steps followed are:

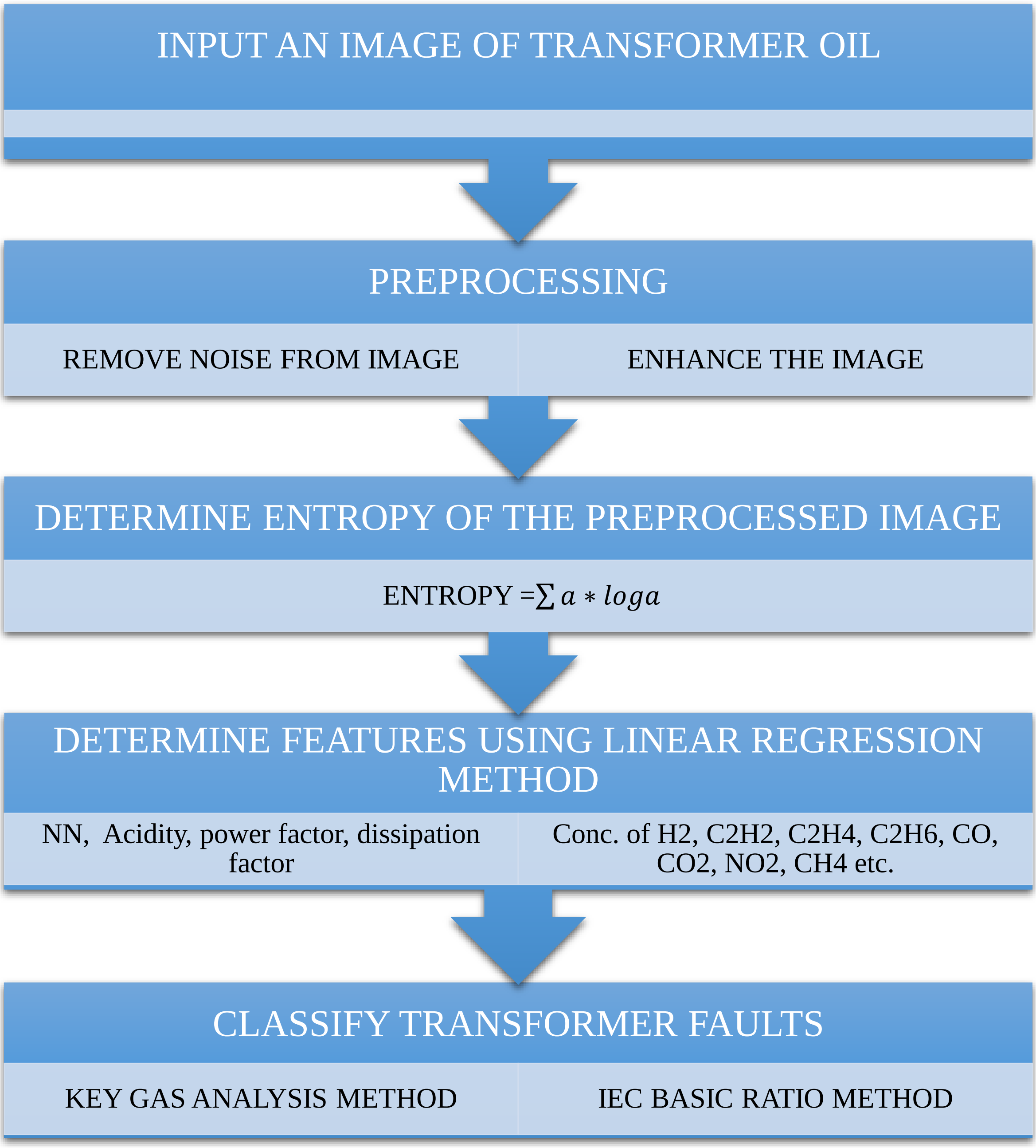

Figure 3.1 flow chart of methodology for image processing based transformer oil analysis

Chapter 4

Preprocessing of Transformer Oil Image

This is the first step of image processing. The microscopic image obtained from blood sample contains noises which can interrupt in image processing detection and may leads to erroneous results. Noise is nothing presence of any unwanted signal which degrades the image signal. Noises can be generated from apparatus or from environment.

DENOISEOF TRANSFORMER OIL IMAGE

The main types of noises in microscopic images of blood sample are

A. Gaussian white noise and

B. Salt and pepper noise

• Salt and pepper noise: This is also referred to as impulse noise as is characterized by sudden high amplitude yet for short disturbance which results in increasing the pixel values to a high level at some points. This is scattered randomly.

• Gaussian noise: It is a randomly fluctuated white noise.

These noises can be removed by median filter and wiener filter. Median filter takes pixel values from the surrounding of a particular point and returns the average of all in to the point. Thus it is used to remove salt and pepper filter.

Weiner filter works on the principle of least squares. Suppose an distorted image M' is given which after restoration gives value R but undistorted image be M. closeness of R to M can be measured by

$$\sum (\mathrm{mij} - \mathrm{rij})^2$$

Thus minimum error can be found out by least square method. This is used to remove Gaussian noise.

IMAGE ENHANCEMENT

This is an important preprocessing tool which results in appreciate visual conception and helps in further processing of image. This is subjective i.e. the different methods to be applied is application dependent.

The key functions are:

i. Deblurring of an image.

ii. Sharpening of an image

iii. Improving brightness and contrast of an image

iv. Proper edge highlighting etc.

HISTOGRAM MODIFICATION

In the microscopic images the majority of pixels possess a luminescence less than average which results into poor visual effect. Histogram modification is a tool which pixels will be rescaled to values where there is a well distinguish between their pixel values and thus better to analyze it.

Chapter 5

Linear Regression Method

Linear regression is a method which models for establishing relationship between an independent variable(s) and a dependent variable. Mainly linear regression is divided into two parts: simple regression and multiple regression. Simple regression establishes the relationship between one independent and one dependent variable. Multiple regression models relationship between multiple independent variables and one dependent variable.

Linear regression is nothing but a linear predictor where the model parameter are found out by learn data set and using these parameters the unknown values are estimated. Linear regression has enormous practical application as it is very simple to estimate the unknown parameters and thus very easy to predict the unknown values.

Most often the variable(s) upon which our prediction is based is called predictor variable referred to as 'X' and the variable whose value we want to find out is called criterion variable. In linear regression method we want to find the best fitted curve which is referred as regression line. The best fitted line is the line from which error of all the points on an average is small. This error is minimized by least square method. This method establishes a line from which the sum of the squares of the error of all points is the least.

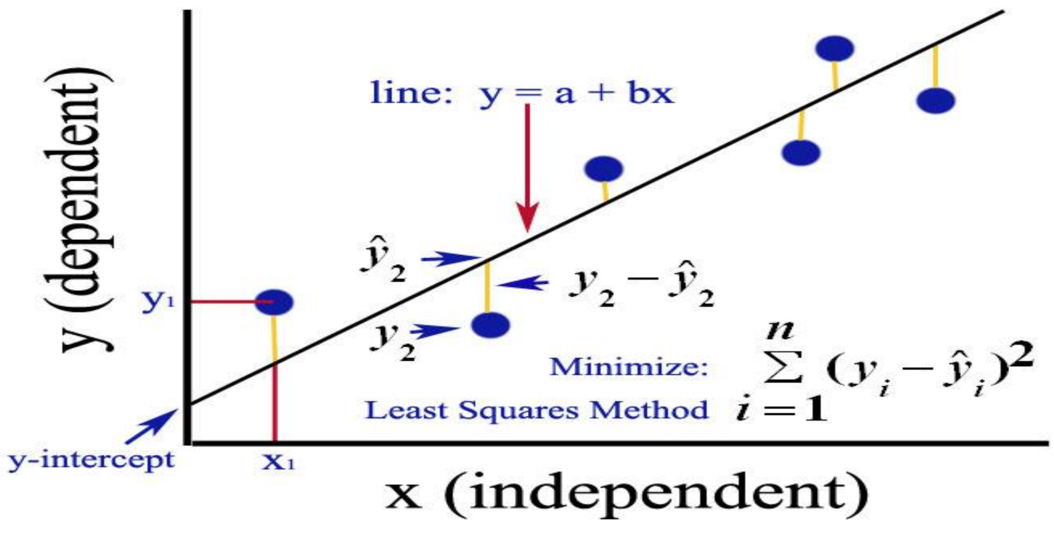

Figure 5.1 linear regression curve

Let the relation between x and y be as follows:

$y = bx + a$ ……………………………………………………………(7)

Where y is known as the predictor variable and x is known as the criterion variable. Now we have to find the values of the slope (b) and the predictor variable intercept (a).

Let x1, x2, …xn be the given criterion variables and corresponding to these y1, y2….yn be the given predictor values and we have to find predict the value at x=x0.

Firstly, we find the $y1', y2', \ldots \ldots \ldots \ldots yn'$ as

$y1' = bx1 + a$ ……………………………………………………….(8.1)

$y2' = bx2 + a$ ……………………………………………………….(8.2)

…………

………..

$yn' = bxn + a$ ……………………………………………………….(8.n)

Now the errors are:

$\in 1 = y1 - y1'$ ……………………………………………………….(9.1)

$\in 2 = y2 - y2'$ ……………………………………………………….(9.2)

……………………..

……………………..

$\in n = y1 - y1'$ ……………………………………………………….(9.n)

Thus the sum of square is

$S = \in 1^2 + \in 2^2 + \in 3^2 \ldots\ldots\ldots\ldots.. + \in n^2$……………………….……….(10)

By solving for the least possible S[11]i.e. minimum value of sum of the squares of the error we have,

$b = r\frac{Sy}{Sx}$ ……………………………….……………………………(11)

$a = My - b\ Mx$………………………………………........………..(12)

Where,

Mx= mean of criterion values,

My= mean of predictor values,

Sx= S.D. of criterion values,

Sy= S.D. of predictor values and

r= correlation between given criterion and predictor data.

NOTE:

S.D. stands for standard deviation.

5.1 ALGORITHM FOR FINDING UNKNOWN VALUE:

1. Input the predictor data set and criterion data set as y1,y2….yn and x1, x2…..xn respectively.
2. Find mean of the predictor and criterion data set as My and Mx respectively.
3. Find standard deviation of the predictor and criterion data set as Sy and Sx respectively.
4. Find correlation of the predictor and criterion data set as r.

5. Write predictor intercept (b) as b= r* Sy/Sx;
6. Write slope (a) as a= My- b*Mx
7. Now the required value is given by y0= a*x0+b

Chapter 6

Detection of Different Types Faults from Gas Concentrations in Oil

There are many causes of forming gases in the transformer oil but the main two are thermal disturbances and electrical disturbances. Due to copper and core loss in conductor the temperature is increased and which forms thermal decomposition of the insulations present in paper and oil in which different gases are formed. These gases are mainly formed due to ionic bombardment.

6.1 CELLULOSIC DECOMPOSITION [8]

Due to decomposition of paper insulation which mainly consists of cellulose produces CO, CO_2, H_2, and CH_4. The amount of production of these gases are related exponentially to the temperature and also dependent of volume. As the volume increases these amount increases.

6.2 OIL DECOMPOSITION [8]

Transformer oil is a mixture of a number of gases, thus the analysis of decomposition of transformer oil is quiet complex. Basically first step is the breakdown of C-H and C-C bonds which results into active H atom and other hydrocarbon fragments. These are prone to with each other to form H_2, CH_4, and C_2H_6 etc. Facilitated by temperature this further undergoes decomposition and rearrangement to form C_2H_4, C_2H_2 etc.

Here two methods are applied to find the kind of fault from the concentration of H_2, CO, C_2H_2, CO_2, C_2H_4, C_2H_6, CH_4, N_2 and O_2. These are as follows:

1. KEY GAS ANALYSIS METHOD and
2. IEC BASIC RATIO METHOD

6.3 KEY GAS ANALYSIS METHOD [5]

This analytic method is useful to detect the fault caused by presence of a single gas predominantly. The range of ppm level presence of a particular gas leads to different characteristic faults in transformer oil. This method indicates the fault level from the comparison of the concentration of the key gas with the reference.

Table 6.1Different conditions for key gas analysis method [12]

Gas	Normal Condition	Abnormal Condition	Interpretation
H_2	< 150 ppm	> 1000 ppm	Arcing, Corona
C_2H_6	<10 ppm	>35 ppm	Overheating (local)
CH_4	< 25 ppm	> 80 ppm	Sparking
C_2H_4	<20 ppm	>100 ppm	Overheating (severe)
N_2	1 to 10%	N.A.	N.A.
CO_2	<10000 ppm	>15000 ppm	Overloading (Severe)
O_2	0.2 to 3.5%	.03%	Combustibles
CO	<500 ppm	>1000 ppm	Overloading (Severe)

6.3.1 GUI MODEL FOR KEY GAS ANALYSIS METHOD:

This graphic user interface model very user friendly which enables the user to input the concentration of different gases in the boxes provided named H_2, CH_4, C_2H_6, C_2H_4, C_2H_2, CO, N_2, CO_2, N_2 etc. by pressing the “EVALUATE KEYGAS METHOD ” the gas contents are analyzed based on key gas method . The user can observe the key gases (CO, H_2, C_2H_4, and C_2H_2) percentage concentration. Finally the user can observe the principal gas involved in the fault and the type of fault.

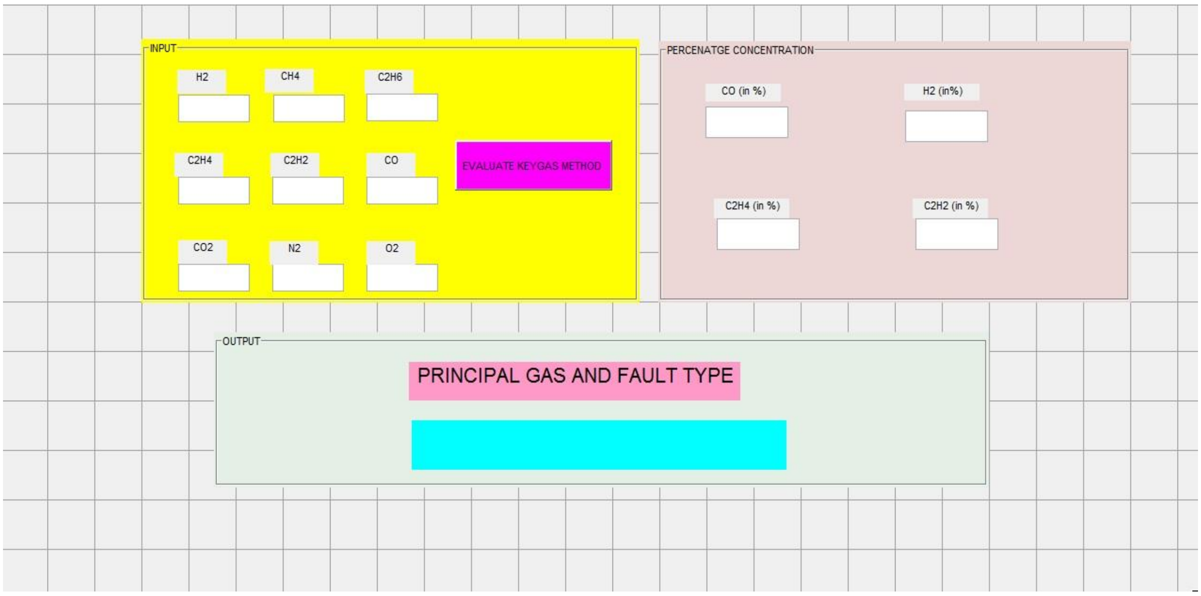

Figure 6.1 GUI model for key gas analysis method

6.4 IEC BASIC RATIO METHOD

Though there are many gases to indicate different faults in transform primarily there are 5 gases (H2, CH4, C2H6, C2H4, and C2H2) which can indicate almost all kind of fault. In this method these 5 gases are taken into consideration. This method compares the ratio of gases with the reference ratio to detect the kind of fault exist in transformer oil. Here only 3 ratios are important:CH4/H2, C2H2/C2H4, and C2H4/C2H6.

Table 6.2 Different conditions for iec basic ratio method [12]

FAULT TYPE	C2H2/C2H4	CH4/H2	C2H4/C2H6
Normal	<0.1	0.1 to 1.0	<1
low energy density partial discharge	Not Significant	<0.1	<1
Thermal fault <150^0C	<0.1	0.1 to 1.0	1-3
thermal fault 150^0C -300^0C	<0.1	>1	<1

Thermal fault $300^0C < t < 700^0C$	<0.1	>1	1-3
Thermal fault $>700^0C$	<0.1	>1	>3
High energy arc discharge	1-3	<0.1	>3
Low energy but continuous sparking	>1	<0.1	>1
high energy density partial discharge	1-3	<0.1	<1

6.4.1 GUI MODEL FOR IEC BASIC RATIO METHOD:

This graphic user interface model very user friendly which enables the user to input the concentration of different gases in the boxes provided named H2, CH4, C2H6, C2H4, C2H2, CO, N2, CO2, N2 etc. by pressing the "EVALUATE IEC METHOD " the gas contents are analyzed based on iec basic ratio method . The user can observe the ratios in concentration of the gases i.e. CH4/H2, C2H2/C2H4, and C2H4/C2H6. Finally the user can observe the type of fault.

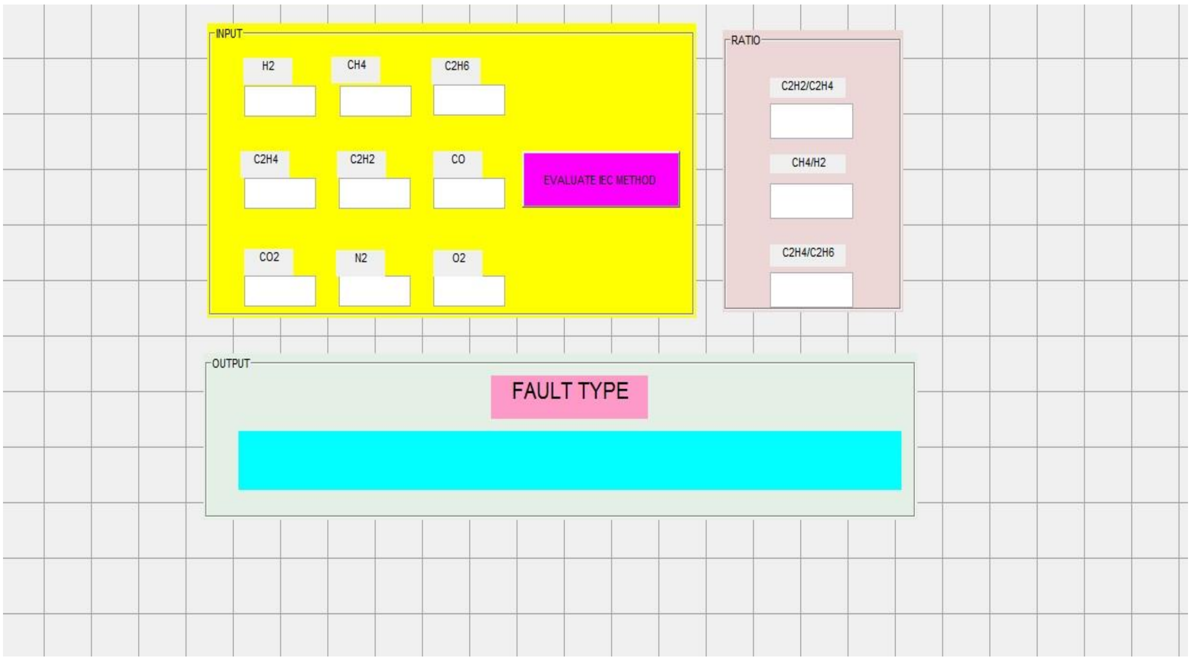

Figure 6.2 GUI model for iec basic ratio method

Chapter 7

MATLAB Codes for Image Processing Based Oil Analysis

7.1 MATLAB CODE FOR PREPROCESSING

```
function y=oilanalysis(I,s)

closeall

%% actual microscopic image

if(ischar(I)==0)

    A =I;

     I = 'Memory';

else

    A=imread(I);

end;

if s==1,figure,imshow(A);title('Input image'); end;

% assuming noise added during image acquisition be salt & pepper and gaussian

B =imnoise(A,'salt& pepper',.02);

if s==1,figure,imshow(B);title('after adding salt and pepper noise'); end;

C=imnoise(B,'gaussian');

if s==1,figure,imshow(C);title('after adding gaussian noise'); end;

%% NOISE REDUCTION BY WEINER2 AND MEDFILT2 FILTER2

Dr=medfilt2(C(:,:,1));

Dg=medfilt2(C(:,:,2));

Db=medfilt2(C(:,:,3));

D=cat(3,Dr,Dg,Db);

if s==1,figure,imshow(D);title('after filtering through med2filt2'); end;

Er=wiener2(D(:,:,1));

Eg=wiener2(D(:,:,2));
```

```
Eb=wiener2(D(:,:,3));
E=cat(3,Er,Eg,Eb);
if s==1,figure,imshow(D);title('after filtering through weiner2');end;
%% IMAGE ENHANCEMENT BY IMADJUST AND HISTEQ
[F1,map]=rgb2ind(E,65536);
F1=ind2rgb(F1,map);
F1=rgb2ntsc(F1);
F1(:,:,1)=histeq(F1(:,:,1));
F=ntsc2rgb(F1);
figure,imshow(F);title('after histeq');
[G1,map]=rgb2ind(F,65536);
G1=ind2rgb(G1,map);
G1=rgb2ntsc(G1);
G1(:,:,1)=imadjust(G1(:,:,1));
G=ntsc2rgb(G1);
figure,imshow(G);title('after imadjust');
```

7.2 MATLAB CODE FOR REGRESSION MODEL:

```
function Y=regression(D,X)
x=D(:,1);
y=D(:,2);
n=length(x);
mx=0;
my=0;
sx=0;
```

```
sy=0;
r=0;
mxx=0;
myy=0;
mxy=0;
fori=1:n
mx=mx+D(i,1);
my=my+D(i,2);
mxx=mxx+D(i,1)^2;
myy=myy+D(i,2)^2;
mxy=mxy+D(i,1)*D(i,2);
end
Mx=mx/n;
My=my/n;
fori=1:n
sx=sx+(D(i,1)-Mx).^2;
sy=sy+(D(i,2)-My).^2;
end

Sx=sqrt(sx/n);
Sy=sqrt(sy/n);
r=mxy/(sqrt(mxx*myy));
display(Mx)
display(My)
display(Sx)
```

```
display(Sy)
display(r)

b=r*Sy/Sx;
A=My-b*Mx;
display(b);
display(A);

Y=b*X+A;
```

7.3 MATLAB CODE FOR KEY GAS ANALYSIS METHOD:

```
clc
clear all
% initialization of all key gases concentration
a=input(' please enter the value of H2 in ppm = ')
b=input('please enter the value of CH4 in ppm = ')
c=input('please enter the value of C2H6 in ppm = ')
d=input('please enter the value of C2H4 in ppm = ')
e=input('please enter the value of C2H2 in ppm = ')
f=input('please enter the value of CO in ppm = ')
g=input('please enter the value of CO2 in ppm = ')
h=input('please enter the value of N2 in ppm = ')
z=input('please enter the value of O2 in ppm =')
% checking wheather fault exist or not
```

```
if (f>1000 ||b>1500 ||e>150 ||f>7)
    disp('fault exist')
    % checking which type of fault exist
    s=a+b+c+d+e+f+g+h+z
    tg=a+b+c+d+e+f+g+h+z
    tcg=a+b+c+d+e+f
    disp('CO in percentage')
    i=f./s.*100
     disp('H2 in percentage')
    j=a./s.*100
     disp('Ç2H4 in pencentage')
    m=d./s.*100
    disp('Ç2H2 in percentage')
     n=e./s.*100
    % condition checking for faults
    if i>=70
        disp(' principal gas=CO')
        disp('fault type=over heated cellulose')
    else
        if j>=60
            disp('principal gas=H2')
            disp('fault type=corona in oil')
        else
         if n>=30
             disp('principal gas=acetylene')
```

```
                disp('fault type=arcing in oil')
            else
              if m>=50
                  disp('principal gas=ethylene')
                  disp('fault type=over heated in oil')
      else
        disp('fault cannot be find by this method')
      end
     end
      end
    end
else
    disp('normal')
end
```

7.4 MATLAB CODE FOR IEC BASIC RATIO ANALYSIS

```
clc
clear all
% initialization of all key gases concentration
a=input('please enter the value of H2 in ppm = ')
b=input('please enter the value of CH4 in ppm = ')
c=input('please enter the value of C2H6 in ppm = ')
d=input('please enter the value of C2H4 in ppm = ')
e=input('please enter the value of C2H2 in ppm = ')
```

```
f=input('please enter the value of CO in ppm = ')

g=input('please enter the value of CO2 in ppm = ')

h=input('please enter the value of N2 in ppm = ')

z=input('please enter the value of O2 in ppm =')

% checking wheather fault exist or not

disp('IEC ratio method')

tg=a+b+c+d+e+f+g+h+z

tcg=a+b+c+d+e+f

if tcg>=500

   disp('IEC ratio analysis result indicate below is more significant')

else

   disp('IEC ratio analysis result indicate below is less significant')

end

disp('C2H2/C2H4')

l=e./d

if l<0.1

   disp('code=0')

elseif (l>0.1 &l<3.0)

   disp('code=1')

else

   disp('code=2')

end

disp('CH4/H2')

i=b./a

if i<0.1
```

```
    disp('code=1')
elseif(j>0.1 &i<1.0)
    disp('code=0')
else
    disp(' code=2')
end
disp('C2H4/C2H6')
k=d./c
if k<1.0
    disp('code=0')
elseif (k>1.0 &k<3.0)
    disp('code=1')
else
    disp('code=2')
end
% type of fault analysis by IEC ratio analysis
if(l<0.1 &i>0.1 &i<1.0 &k<1.0)
    disp(' normal ageing')
    disp(' fault code=f6')
elseif (l<0.1 &i>0.1 &i<1.0 &k>1.0 &k<3.0)
    disp('thermal fault<150c')
    disp('fault code=f1')
elseif (l>0 &i<0.1 &k<1.0)
    disp('partial discharge of low energy density')
    disp('fault code=f4')
```

```
elseif (l<0.1 &i>1.0 &k<1.0)

    disp('thermal fault 150c-300c')

    disp('fault code=f1')

elseif (l<0.1 &i>1.0 &k>1.0 &k<3.0)

    disp('thermal fault 300c-700c')

    disp('fault code=f2')

elseif (l<0.1 &i>1.0 &k>3.0)

    disp('thermal fault >700c')

    disp('fault code=f3')

elseif (l>1.0 &l<3.0 &i<0.1 &k>3.0)

    disp('arc with with power flow,discharge of high energy')

    disp('fault code=f5')

elseif (l>1.0 &i<0.1 &k>1.0)

    disp('contnious sparking,discharge of low energy')

    disp('fault code=f5')

elseif(l>1.0 &l<3.0 &i<0.1 &k<1.0)

    disp('partial discharge high energy density')

    disp('fault code=f4')

else

    disp('out of range,data is not definable by IEC ratio method')

    disp('fault code=f7')

end
```

Chapter 8

Result Analysis

After preprocessing of images collected from [1] are as shown:

Figure 8.1 Fresh oil transformer oil

Figure 8.2 Three year aged transformer oil

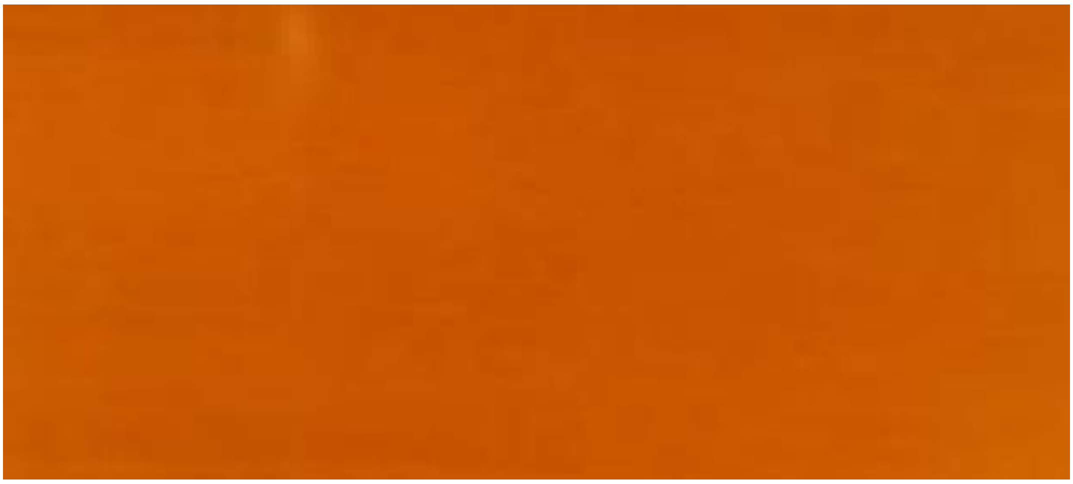

Figure 8.3 Nine year aged transformer oil

Figure 8.4 Twelve year aged transformer oil

Figure 8.5 Fourteen year aged transformer oil

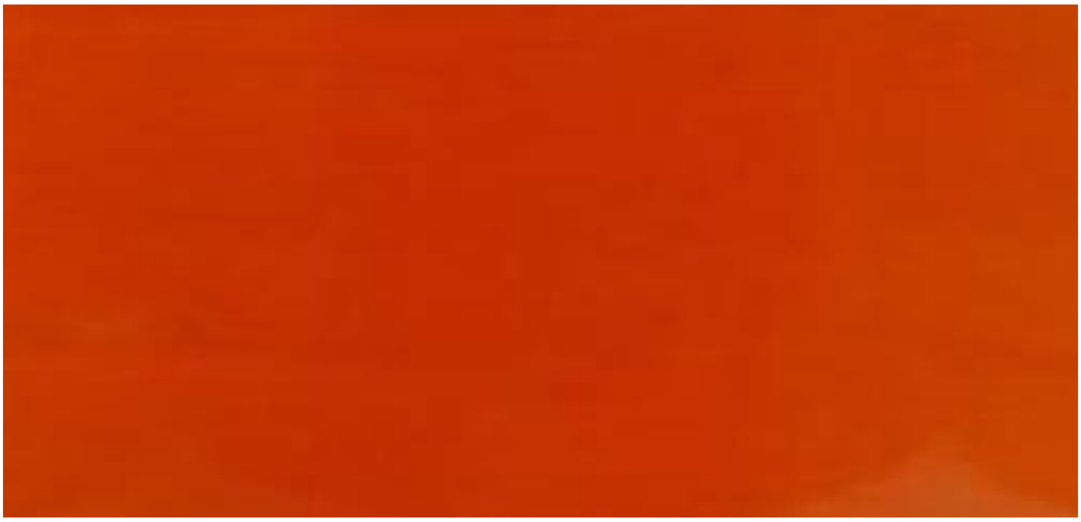

Figure 8.6 Sixteen year aged transformer oil

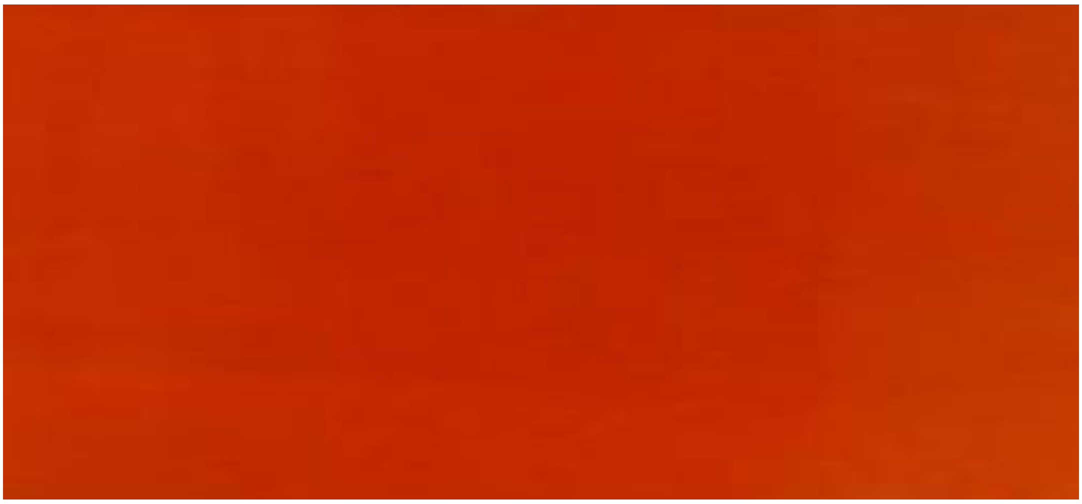

Figure 8.7 Seventeen year aged transformer oil

Figure 8.8 Eighteen year aged transformer oil

Figure 8.9 Twenty-one year aged transformer oil

Figure 8.10 Twenty-five year aged transformer oil

8.1 REGRESSION MODEL FOR DETERMINATION OF NN, IFT, DISSION FACTOR AND POWER FACTOR:

Data collected from [1]

8.1.1 INPUT DATA:

Table 8.1 Characteristic properties of different oil samples

	Entropy value	**Sample ageing year**	NN (in mg)	IFT	DISSIPATION FACTOR	**POWER FACTOR**
Fresh oil	0.8003	1	.013	24	.0020	.0020
3yr aged oil	2.9409	2.6	.043	24	.0050	.0050
9yr aged oil	3.3973	10.65	.1510	24	.0220	.0179
12yr aged oil	3.6983	12.82	.179	20	.0260	.0240
16yr aged oil	3.8009	14.15	.196	20	.0290	.0280

17yr aged oil	3.8193	16.08	.268	20	.1150	.1070
18yr aged oil	3.8986	18.02	.3	16	.1290	.1190
21yr aged oil	4.2883	18.28	.3	16	.1310	.1240

8.1.2 RESULT:

The given data is processed using the regression model.

Here x=entropy of image data

Y= different properties like sample ageing year, neutralization number(NN), interfacial tension (IFT), dissipation factor(tan δ) and power factor.

Mx= mean of x data

My= mean of y data

Sx= S.D. of x data

Sy=S.D. of y data

r= correlation between x and y data

b= slope of regression line

a= y intercept for regression line

y(3)= value of y at x=3.

Table 8.2 Estimation of different properties of oil using regression model

	ENTROPY	SAMPLE AGEING YEAR	NN (in mg)	IFT	DISSIPATION FACTOR	POWER FACTOR
Mx	3.3305	3.3305	3.3305	3.3305	3.3305	3.3305
My	3.8894	11.6975	0.1813	20.5000	0.0574	0.0534
Sx	1.0243	1.0243	1.0243	1.0243	1.0243	1.0243
Sy	0.2956	6.2030	0.1026	3.1225	0.0533	0.0499
r	0.9728	0.9640	0.9535	0.9146	0.8252	0.8233
b	0.2808	5.8377	0.0955	2.7881	0.0429	0.0401
a	2.9543	-7.7449	-0.1370	11.2143	-0.0856	-0.0802
y(3)	3.7966	9.7682	0.1497	19.5786	0.0432	0.0401

8.2 REGRESSION MODEL FOR DETERMINATION OF CONCENTRATION OF DIFFERENT GASES PRESENT IN TRANSFORMER OIL

These data are taken randomly considering the boundary condition of all the gases.

8.2.1 INPUT DATA:

Table 8.3 Different gas concentration of different oil samples

	Entropy value	**H2**	**CH4**	**C2H6**	**C2H4**	**C2H2**	**CO**
Fresh oil	0.8003	22	34	5	8	19	73
3yr aged oil	2.9409	73	61	16	34	34	234
9yr aged oil	3.3973	233	143	23	54	45	354

12yr aged oil	3.6983	394	265	29	63	63	391
16yr aged oil	3.8009	797	345	38	83	74	478
17yr aged oil	3.8193	934	756	44	112	93	534
18yr aged oil	3.8986	1098	983	54	142	111	738
21yr aged oil	4.2883	1287	1123	63	134	123	1089

Here x=entropy, and

y= gas (H2, C2H6, CH4, C2H4, CO, C2H2, CO2)concentration in ppm.

Applying the regression method Mx, My, Sx, Sy, r, a, b and value of y at x=3 is tabulated as follows.

Table 8.4 Estimation of concentration of different gases present in oil using regression model

	H2	CH4	C2H6	C2H4	C2H2	CO
Mx	3.3305	3.3305	3.3305	3.3305	3.3305	3.3305
My	604.7500	463.7500	34	78.7500	70.2500	490.1250
Sx	1.0243	1.0243	1.0243	1.0243	1.0243	1.0243
Sy	455.3976	402.0288	18.2620	44.7849	34.6509	297.0452
R	0.8945	0.8486	0.9570	0.9481	0.9607	0.9336
B	397.6980	333.0824	17.0626	41.4530	32.4994	270.7502
A	-719.7782	-645.5769	-22.8268	-59.3087	-37.9887	-411.6051
y(3)	473.3158	353.6704	28.3610	65.0503	59.5094	400.6455

8.3 FAULT DETERMINATION USING KEY GAS METHOD

8.3.1 Experiment 1:

Sample 1 data: conc. of different gases

Table 8.5 Conc. of different gases in sample 1

Sl. No.	Gas Name and symbol	Gas conc. In ppm
1	Hydrogen (H2)	73
2	Methane (CH4)	14
3	Ethane (C2H6)	25
4	Ethene (C2H4)	22
5	Ethyne (C2H2)	2
6	Carbon monooxide (CO)	73
7	Carbon dioxide (CO2)	143
8	Nitrogen (N2)	12
9	Oxygen (O2)	34

After analyzing sample 1 data using key gas method we have the following table.

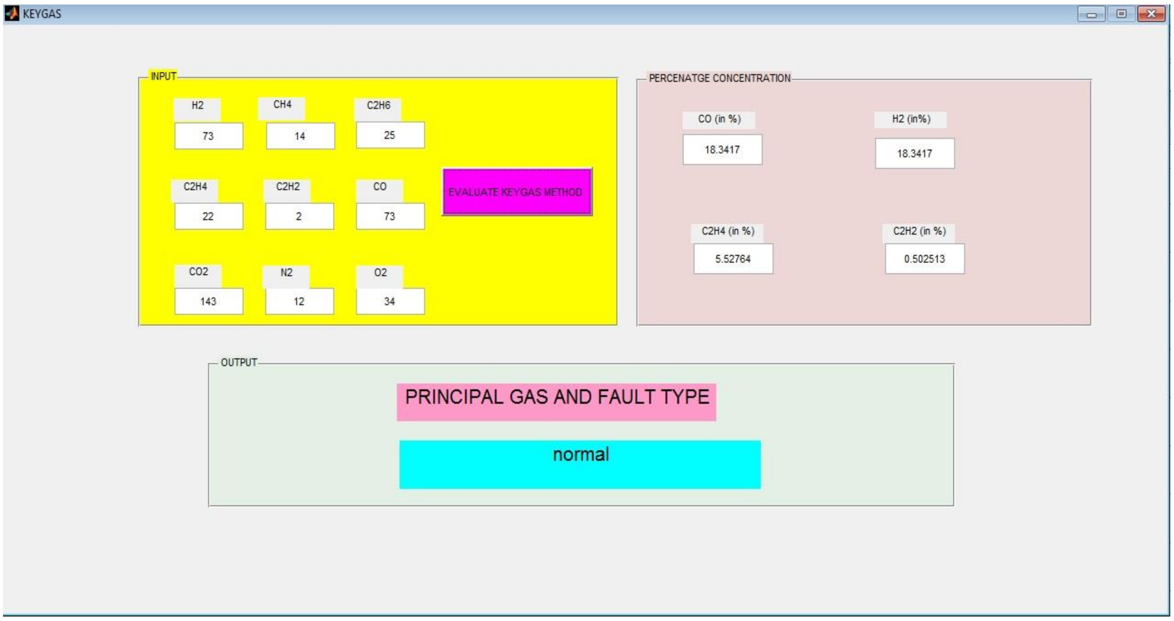

Figure 8.11 GUI model in key gas analysis method for sample1

8.3.2 Experiment 2:

Sample 2 data: conc. of different gases

Table 8.6 Conc. of different gases in sample 2

Sl. No.	Gas Name and symbol	Gas conc. In ppm
1	Hydrogen (H2)	22
2	Methane (CH4)	14
3	Ethane (C2H6)	25
4	Ethene (C2H4)	22
5	Ethyne (C2H2)	2
6	Carbon monooxide (CO)	73
7	Carbon dioxide (CO2)	830
8	Nitrogen (N2)	12
9	Oxygen (O2)	34

After analyzing sample 2 data using key gas method we have the following figure

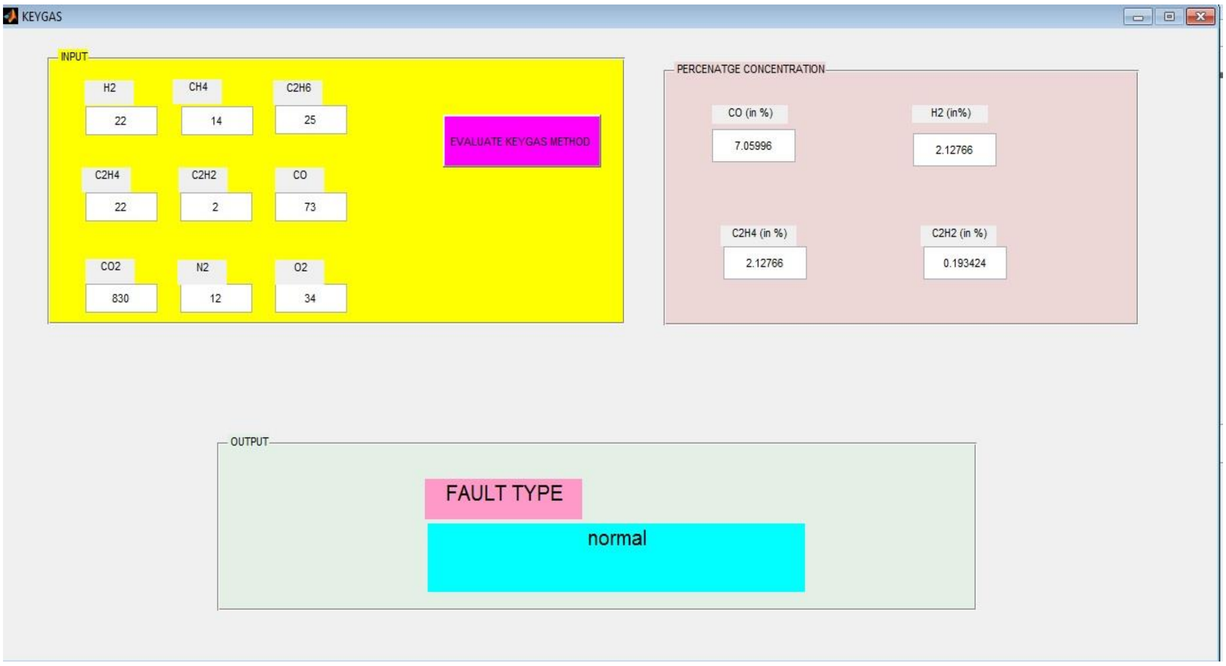

Figure 8.12 GUI model in key gas analysis method for sample2

8.3.3 Experiment 3:

Sample 3 data: conc. of different gases

Table 8.7 Conc. of different gases in sample 3

Sl. No.	**Gas Name and symbol**	**Gas conc. In ppm**
1	Hydrogen (H2)	74
2	Methane (CH4)	66
3	Ethane (C2H6)	39
4	Ethene (C2H4)	34
5	Ethyne (C2H2)	3
6	Carbon monooxide (CO)	123
7	Carbon dioxide (CO2)	22
8	Nitrogen (N2)	15
9	Oxygen (O2)	83

After analyzing sample 3 data using key gas method we have the following figure.

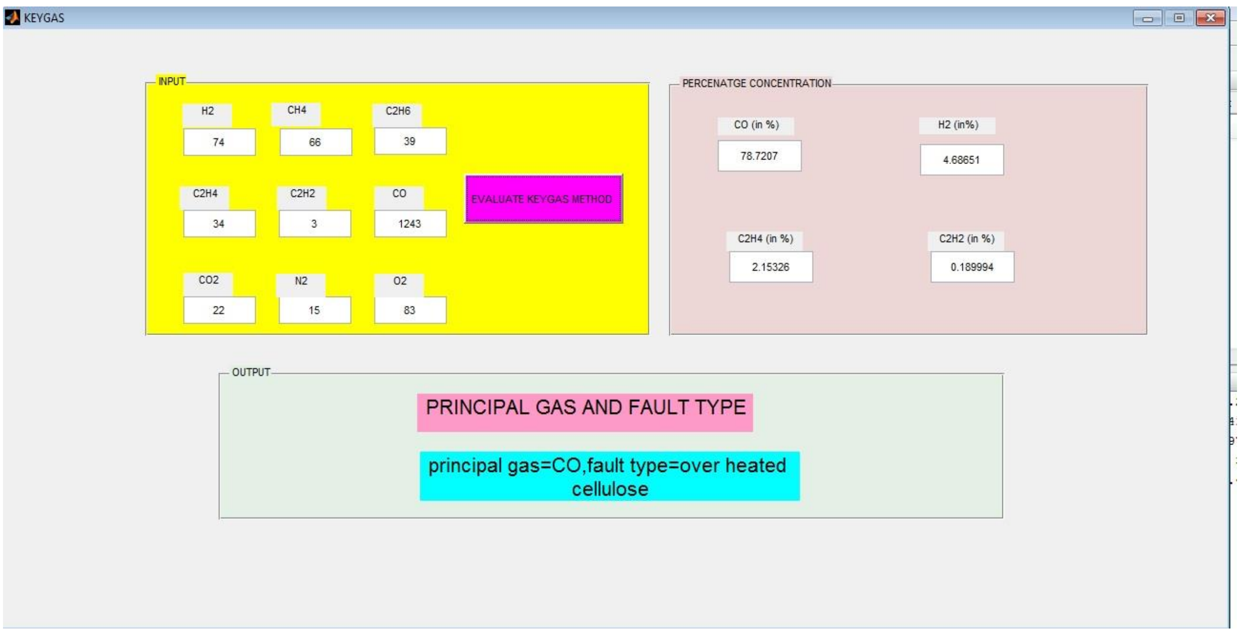

Figure 8.13 GUI model in key gas analysis method for sample 3

8.4 FAULT DETERMINATION USING IEC BASIC RATIO METHOD:

8.4.1 Experiment 4:

Sample 4 data: conc. of different gases

Table 8.8 Conc. of different gases in sample 4

Sl. No.	Gas Name and symbol	Gas conc. In ppm
1	Hydrogen (H2)	73
2	Methane (CH4)	61
3	Ethane (C2H6)	35
4	Ethene (C2H4)	34
5	Ethyne (C2H2)	3
6	Carbon monooxide (CO)	234
7	Carbon dioxide (CO2)	214
8	Nitrogen (N2)	17
9	Oxygen (O2)	45

After analyzing sample 4 data using iec basic ratio method we have the following figure.

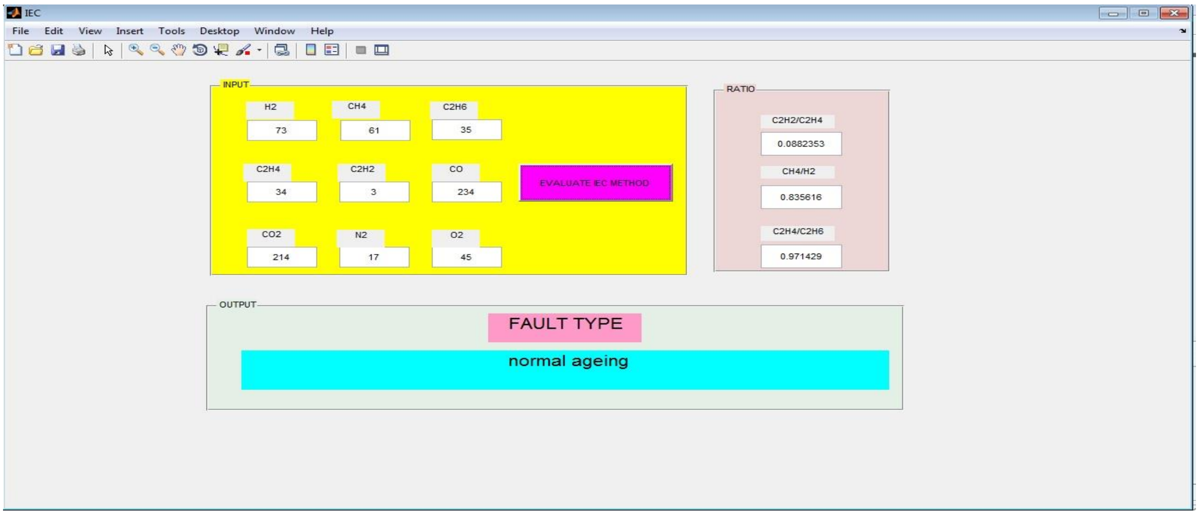

Figure 8.14 GUI model in iec basic ratio method for sample1

8.4.2 Experiment 5:

Sample 5 data: conc. of different gases

Table 8.9 Conc. of different gases in sample 5

Sl. No.	Gas Name and symbol	Gas conc. In ppm
1	Hydrogen (H2)	22
2	Methane (CH4)	14
3	Ethane (C2H6)	25
4	Ethene (C2H4)	22
5	Ethyne (C2H2)	2
6	Carbon monooxide (CO)	73
7	Carbon dioxide (CO2)	143
8	Nitrogen (N2)	12
9	Oxygen (O2)	34

After analyzing sample 5 data using iec basic ratio method we have the following figure

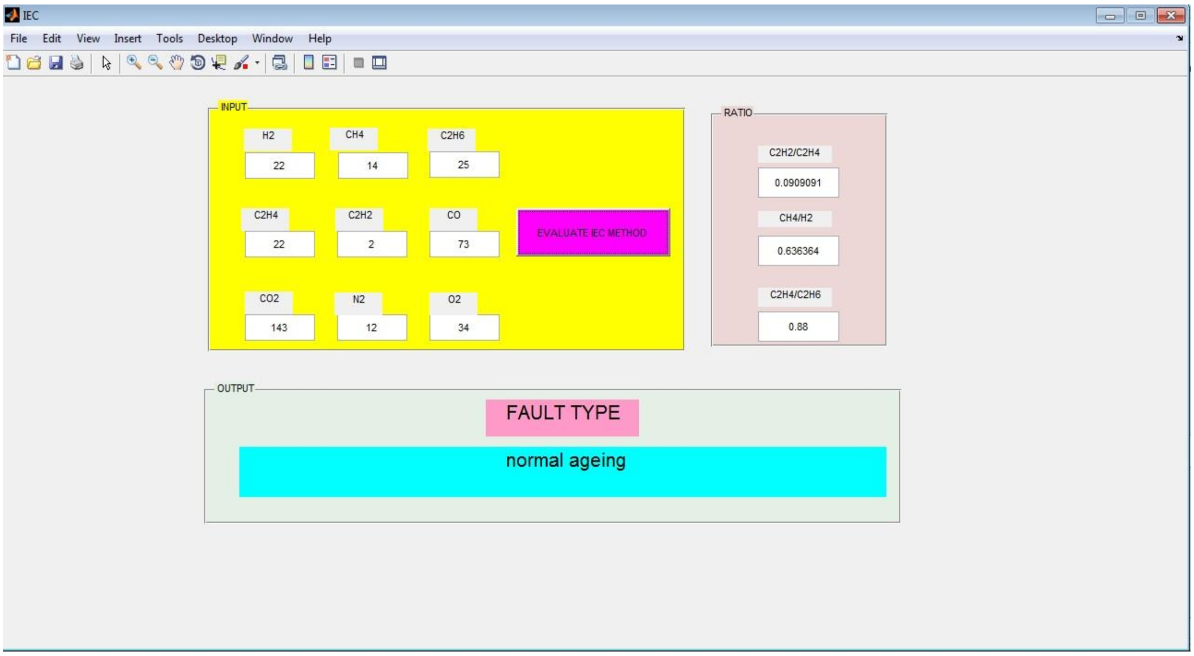

Figure 8.15 GUI model in Iec basic ratio method for sample2

8.4.3 Experiment 6:

Sample 6 data: conc. of different gases

Table 8.10 Conc. of different gases in sample 6

Sl. No.	Gas Name and symbol	Gas conc. In ppm
1	Hydrogen (H2)	73
2	Methane (CH4)	6
3	Ethane (C2H6)	86
4	Ethene (C2H4)	1
5	Ethyne (C2H2)	3
6	Carbon monooxide (CO)	234
7	Carbon dioxide (CO2)	214
8	Nitrogen (N2)	17
9	Oxygen (O2)	45

After analyzing sample 6 data using iec basic ratio method we have the following table.

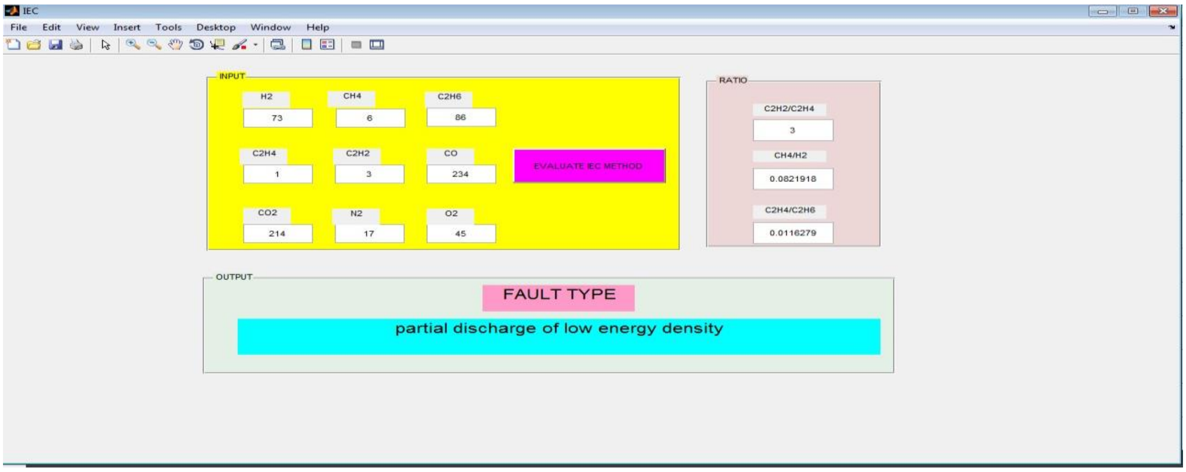

Figure 8.16 GUI model in iec basic ratio method for sample3

Thus by following these procedures one can able to detect any fault that occurs in the transformer oil. According to table no. 8.1 and 8.2, the manually estimated fault type matches with the fault detected in the key gas analysis method and iec basic ratio method.

Chapter 9

Conclusion and Future scope

Image processing technique for transformer oil analysis is software based analytic technique which is fast, reliable and user friendly. Median and weinner2 filters were used to filter out the white Gaussian and salt and pepper noise (if any). Using histogram modification techniques the image quality was enhanced for better visibility and analysis. Entropy technique was used to find out different oil properties like NN, dissipation factor, power factor etc. to determine the performance of transformer. Using regression model was used to establish the relation between different entropy extracted from the image and NN, dissipation factor, power factor and to find the NN, power factor, dissipation factor (tan δ) etc. of the sample. Also the same regression model is used to find out the Different gas (CH_4, C_2H_4, C_2H_2, C_2H_6,H_2, CO_2, CO, NO_2 and O_2)contents in ppm level in a transformer oil sample. Two methods i.e. KEY GASMETHOD and IEC BASIC RATIO METHOD are used to determine the different types of faults occurred in a transformer by the concentrations of different gases present in the oil sample. Thus this project provides an easy and fast method to check the transformer health from the image of transformer oil.

FUTURE SCOPE:

This project can be built in an android, java and windows platform to be runin a mobilewhich will be quiet reliable and user friendly. More no. of experiment data can be used to validate this practically fit enough to replace the other methods of analysis. Data from different types, ratings of transformers can be used to standardize the process for a class of transformers. Instead of linear regression method non-linear predictor methods can be used to model a realistic relation which will provide excellent accuracy.

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