Applet Java Applied Fault Interpretation in Power Apparatus using Dissolved Gas Analysis

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Abstract: **To adapt the changing environments and uses and to implement refinements and improvements in the art of programming java is chosen for implementing a simple algorithm in protecting a Power Apparatus (PA), in which the limiting of damage becomes a by-product of the Protection System Function. To interpret the type of fault by analysing the dissolved gases which have evolved from the Insulation Media of the Apparatus and dissolved in the oil, a simple algorithm is developed and implemented in Java. To interpret the faults occurring in Power Apparatus like Power Transformers (PT), Load Tap Changers (LTC) and Bushings from the Dissolved Gas Analysis (DGA) data, the Algorithm Hexagon is developed that interprets the faults when the DGA data is imported and a visual presentation is reported. This window based Hexagon of applet java developed in java version jdk 1.6.0 may be useful for data sets pertaining to DGA of mineral or non mineral oil in PT, LTC or Bushings and to a Control and Protection Engineer in the Electricity Transmission and Distribution side .**

Keywords: *Applet Java, Hexagon, Dissolved Gas Analysis, Power Apparatus, Power Transformers.*

1. Introduction

For the interpretation of the type of fault by analysing the dissolved gases which have evolved from the Insulation Media of the Apparatus and dissolved in the oil, a simple algorithm is developed and implemented in Java. An application is a program that runs on computer under operating system of the computer. That is an application created by Java is more or less like one created using C or C++. An applet is a window based tiny java program. As such its architecture is different from the so called normal, console based programs. Applets which are event driven resemble a set of interrupt service routines. In applet the user interacts as events to which the applet waits until an event occurs and responds. The important difference is that an applet is an intelligent program, not just an animation or media file. An applet is a program that can react to user input and dynamically change. The applet begins with import statements. Applet interacts with the user through the abstract windowing toolkit (AWT), not through the console based I/O classes. The AWT contains support for a window based, graphical interface. Every applet that is created must be a subclass of Applet. The class in the Applet must be declared as public, because it will be accessed by code that is outside the program. Once an applet has been compiled, it is included in an HTML file using the APPLET tag. The applet will be executed by a Java enabled web browser when it encounters the APPLET tag within the HTML file. The AWT notifies the applet about an event by calling an event handler that has been provided by the applet. Once this happens, the applet must take appropriate action and then return and then quickly return control to the AWT.

The window based Hexagon of applet java developed in java version jdk 1.6.0 may be useful for data sets pertaining to DGA of mineral or non mineral oil in PT, LTC or Bushings and to a Control and Protection Engineer in the Electricity Transmission and Distribution side where the Gas Chromatography help the electrical power engineer to device techniques for the identification of fault gases dissolved in transformer insulating oil from the early nineteen sixties [1]. An IEEE standard (C57.104-1991) [2] introduced the DGA as one of the most accepted methods for detecting incipient fault conditions in PTs. The correlation between the DGA and the corresponding fault conditions in the transformers has been well established and formulated and for the routine monitoring of in-service transformers it is used over the past five decades [3]. IEC Standard 60599 and IEEE Standard C 57 provide guidance for the interpretation of DGA results in service [4].

In addition to mineral oil non mineral oils like Midel, Silicone, FR3, and BioTemp are increasingly used as insulating liquids in electrical equipments because they are less flammable and more environmentally friendly. The non mineral oils have high percentage of biodegradability and are more hygroscopic in nature. Due to their high percentage of biogradability and more hygroscopic than mineral oils non mineral oils are slowly introduced into applications like PA insulation and cooling purposes in order to replace the mineral oils as the non mineral oil also has the same DGA fingerprints as mineral oil [5].

Due to its speciality of arc-quenching ability, non mineral liquids evolve gas only by one-fourth of the gas that would have been produced by the regular transformer oil [6]. In this work a simple algorithm is developed in Java platform to interpret faults

- in Equipments like LTC filled with mineral oil
- in Equipments filled with non mineral oils
- in Equipments for low temperature faults where stray gassing of oils [7]may interfere with diagnostics and
- in PT immersed in Mineral oil

The number of characteristic faults due to thermal stress and electrical stress are classified as seven by Duval by using the relative percentages of three gases namely Methane (CH_4), Ethylene (C_2H_6) and Acetylene (C_2H_2). These three gases correspond to the increasing levels of energy necessary to generate gases in transformers in service [8].The gas ratios as well as the relative proportions of gases and the rules from case studies are used for fault diagnosis from DGA data of mineral oil [9]. A combination of neural network and fuzzy system for enhancing the performance of the diagnostic system has been presented to identify only five types of faults [10].Faults have been analysed and compared with the conventional methods but none of the non mineral liquids have been considered [11]. Evolving wavelet network methodology have been proposed to monitor the condition of only PT immersed in mineral oil [12]. Data from [13-16] and the DGA data samples collected from various substations of South India are used to test this algorithm for fault interpretation. Hexagon is a single algorithm into which the data of fault gases from various PA evolved from mineral as well as non mineral cooling and insulating media is given as input and the type of fault interpreted by the algorithm is obtained as output. All the cases of Equipments and Insulating media can be tested using this single Algorithm Hexagon.

Visually presented information can be accessed by human perception in a most natural way. Complex structures and relation can be perceived in less time in greater number and with fewer errors than in any other way. Models of the real world or Models of abstract concepts are hardly dealt with by humans without taking resort to visual representations. This is the reason why the prediction of faults by visual presentation has been proposed.

2. Interpretation of Fault Gases

In the DGA method oil samples are taken from the transformer at various locations. Then, chromatographic analysis will be carried out on the oil sample to measure the concentration of the dissolved gases. The extracted gases are then separated, identified and quantitatively determined such that the DGA method can then be applied in order to obtain reliable diagnosis [17]. The extracted gases meant for analysis purpose are Hydrogen (H_2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4), Acetylene (C_2H_2), Carbon

Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen (N_2) and Oxygen (O_2). C_2H_2 and C_2H_4 are used in all interpretation methods to represent high energy faults such as arcing and high temperature faults. H_2 is preferred in several of these methods to represent very low energy faults such as PDs, where it is produced in large quantities. CH_4, however, is also representative of such faults and always formed in addition to H_2 in these faults. CH_4 has been chosen rather than H_2 because it not only allows identifying these faults, but provides better overall diagnosis results for all the other types of faults than when using H_2. For the interpretation of faults The Duval Triangle was developed by Michel Duval in 1974 using three of these hydro carbon gases in relative proportions of percentage. Michel Duval proposed regions to represent seven types of faults [8]. The fault zone boundaries proposed by Michel Duval slightly differ when the insulation media differs with different sets of fault gases. The electronic version of the Duval Triangle has to be changed every time when the type of Power Apparatus or the type of insulation media changes [18].

To save time and memory a single algorithm is implemented incorporating all the different zone areas for fault interpretation regardless of whether it is a mineral oil or nonmineral oil or any type of PA. The Interpretation of Faults in the proposed Algorithm Hexagon is listed in Table1. When the data pertains to P3, the algorithm checks for four cases of non mineral liquids, viz. Silicone, FR3, Bio Temp and Midel. These polygons uses the same types of fault gases but their zone boundaries slightly differ. So they are designated as P3S, P3F, P3B and P3M representing Polygon3 for Silicone, Polygon 3 for FR3, Polygon3 for Bio Temp and Polygon3 for Midel respectively. For interpretation of faults in both mineral oil and FR3(Nonmineral oil P6) at low temperatures(P4),the fault gases of importance are H_2, CH_4 and C_2H_6.As the Polygon4 and Polygon6 differ in their inner zone boundaries alone, they are represented by the same polygon with difference in zone boundaries.

TABLE 1. Interpretation of faults in the proposed Hexagon

Location of Point inside the Polygon (Gas Type)/Zone			Interpretation of Type of Fault
Polygon		Zone	
P1 (CH_4,C_2H_4,C_2H_2)		PD	Partial Discharge
		D1	Discharges of low energy
		D2	Discharges of high energy
		T1	Thermal faults of temperature $< 300^0C$
		T2	Thermal faults of temperature $300^0C < T < 700^0C$
		T3	Thermal faults of temperature $>700^0C$.
		DT	Combination of Thermal and Electrical Fault.
P2 (CH_4,C_2H_4,C_2H_2)		N	Normal
		T3	Thermal faults of temperature $>700^0C$.
		X3	Fault T3 or T2 in progress, or severe arcing D2
		T2	Thermal faults of temperature $300^0C < T < 700^0C$
		D1	Abnormal Arcing D1
		X1	Thermal fault in progress
P3	P3S (CH_4,C_2H_4,C_2H_2)	PD	Partial Discharge
	P3F (CH_4,C_2H_4,C_2H_2)	D1	Discharges of low energy
	P3B (CH_4,C_2H_4,C_2H_2)	D2	Discharges of high energy
	P3M (CH_4,C_2H_4,C_2H_2)	T1	Thermal faults of temperature $< 300^0C$
		T2	Thermal faults of temperature $300^0C < T < 700^0C$
		T3	Thermal faults of temperature $> 700^0C$.
		DT	Combination of Thermal and Electrical Fault.
P4 (H_2,CH_4,C_2H_6)		PD	Corona Partial Discharges
		S	Stray Gassing of Mineral Oil
		C	Hotspots $T > 300^0C$
		O	Overheating $T < 250^0C$

P5 (CH_4,C_2H_4,C_2H_6)	PD S C O T3	Corona Partial Discharges Stray Gassing of Mineral Oil Hotspots T > 300^0C Overheating T < 250^0C Thermal faults of very high temperature >700^0C.
P6 (H_2,CH_4,C_2H_6)	PD S C O	Corona Partial Discharges Stray Gassing Hotspots T > 300^0C Overheating T < 250^0C
P7 (CH_4,C_2H_4,C_2H_6)	PD S C O	Corona Partial Discharges Stray Gassing Hotspots T > 300^0C Overheating T < 250^0C

3. Proposed Hexagon in Java Platform

For speedy and easy interpretation of faults in any type of PA , a window based Hexagon is developed in Java, version jdk 1.6.0 to determine visually whether a fault evolves from a relatively harmless thermal fault into a potentially more severe electrical one or not. The Hexagon consists of number of polygons as shown in Fig.1 with respect to that listed in Table .1. The result of implementation of generating the electronic form of hexagon in java platform with the fault coordinates M, N, H, I, J, K obtained inside the different fault zones on implementation of the algorithm is presented in Fig.2. The user friendly phase to import DGA data in Java applet is presented in Fig.3; the user can select the option of his choice by clicking the buttons.

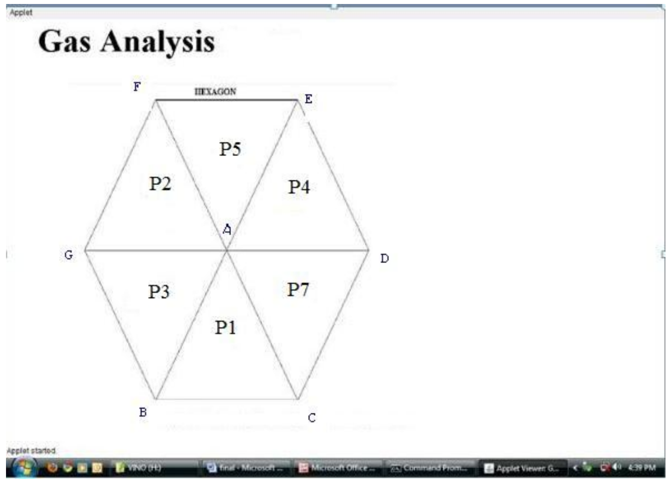

FIG. 1 HEXAGON DIVIDED INTO SIX POLYGONS P1, P2, P3, P4, P5, P7

WITH EACH SIDE OF EACH POLYGON REPRESENTING A GAS VALUE IN %

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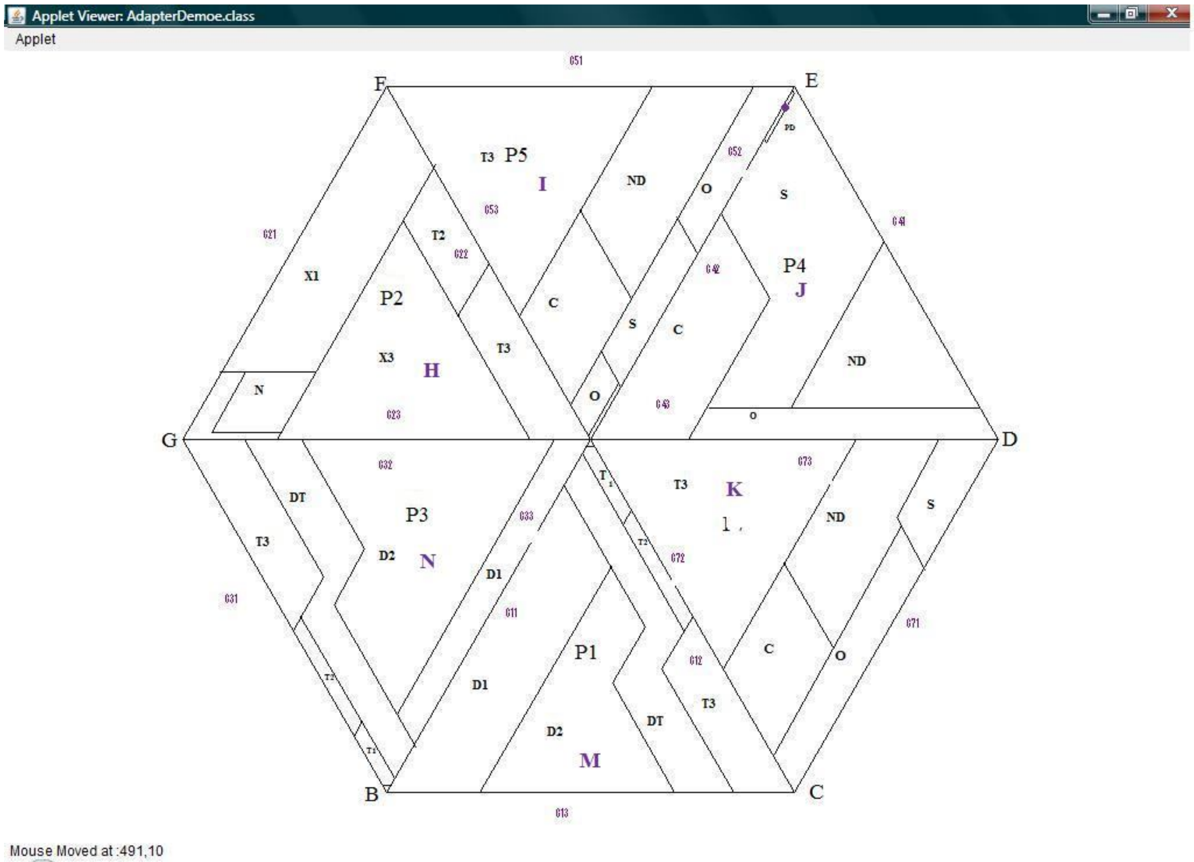


FIG.2.FAULT CO-ORDINATES M, N, H, I, J, K

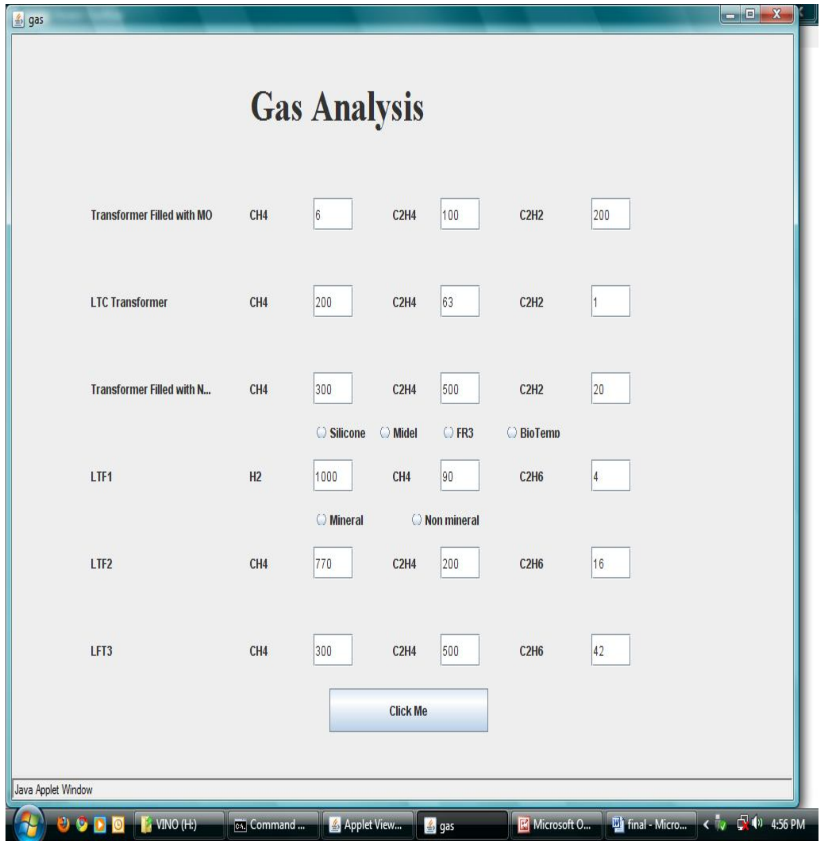


FIG.3. SAMPLE WINDOW OF PHASE II FUNCTION OF THE SOFTWARE WHICH IS USER FRIENDLY

The algorithm is implemented making use of the Cartesian Co-ordinate system. The standard co-ordinate system used on the computer systems differ from that of Cartesian co-ordinate system. The abscissa values of rectangular co-ordinate systems remains the same for the Processor Co-ordinate System, but the Ordinate values are changed by subtracting from the maximum value of the screen resolution. The algorithm developed in this work adopts modular fashion minimizing the number of "goto" statements. The notations used in this algorithm are standard notations as per Jean-Paul Tremblay and Paul G. Sorenson [19].

3.1 Algorithm *Hexagon* This algorithm when implemented in window based Java first draws the Hexagon with polygons and zones inside and then checks the presence of O_2 and N_2 from the n number of DGA data imported to it. If $O_2 / N_2 < 0.3$, then the algorithm tests the Total Combustible Gases (TCG) value and proceeds for further calculation of co-ordinate values corresponding to gas values in percentages of parts per million (ppm) and interpretation of fault. The DGA data imported are integer values and the relative proportions of the gas values are real values.

With respect to coordinates of B (BX and BY), all the coordinates are computed by letting the length of each side of the Hexagon as L. The fault coordinates are calculated taking relative proportions of gas values G11, G12 etc in percentage. For the points that lie on the boundary lines, the probability of the type of fault is predicted by computing a small circular area around that point and evaluating the maximum number of predicted types inside the circle. The fault on the boundary then will be included to the type of fault which resulted as maximum cases of prediction. For example in Polygon 5 in Fig.1 (b), if the point lies on the zone boundary between C [Hot spot with carbonization of paper ($T>300^0C$)] and T3 [Thermal faults of very high temperatures ($T > 700^0C$)], the maximum number of predicted fault around that point if computed belong to T3, then the fault point under prediction is included into the maximum predicted case of fault i.e. T3.

1. [Develop Hexagon,Inner polygons and fault zones]

g.drawPoint

g.drawHexagon

g.drawPolygon

g.drawZone

2.[Import DGA Data and Compute O_2/ N_2 and TCG from DGA Data] (*Phase I*)

[G1, G2, G3, G4]← O_2, N_2,CO,CO_2 (*DGA Data*)

If G1/ G2 < 0.3

Then TCG ← Sum(CH_4,H_2,C_2H_2,C_2H_4,C_2H_6)

Else Exit.

[G11,G21,G33,G42,G52,G71] ←CH_4

[G12,G22,G31,G53,G72]← C_2H_4

[G13,G23,G32]← C_2H_2

[G41]← H_2

[G43,G51,G73]← C_2H_6

3.[Check TCG And Report]

If TCG < 500ppm ,Exit

Else

If 500ppm <TCG<1000 ppm, g.drawString("Significant Decomposition")

Else If

TCG >2500 ppm , g.drawString("Substantial Decomposition")

4.[Determine the type of Power Apparatus] (*Phase II*)

If Mineral Oil , Then

If (C_2H_2 = 10 ppm AND C_2H_4 = 10 ppm)

Then Import Data To P2(*LTC*)

Else Import Data To P1,P4,P5 (*Power Transformer*)

Else (P4 ← P6), Import Data To P3S,P3F,P3B,P3M,P6,P7. (*Non Mineral Oil Data*)

5.[Compute Fault Coordinates M,N,H,I,J,K]

(*Taking the gas values G11,G12 and G13,the Cartesian Co-ordinates of MX and MY are calculated by simple trignometric calculations,and similarly other fault points.*)

$$MX = BX + L*(G12 + G11/2)$$

$$MY=BY + L*(\sqrt{3}/2)G11$$

6.[Interpret fault and Output Result]

```
Select case  ((M,N,H,I,J,K) inside (P1-P10))

    case  P1 : (Z1 thru Z7)
    g.drawString (" fault in Power Transformer immersed in Mineral Oil")
    case P2 : (Z8 thru Z13)
    g.drawString (" fault in LTC  immersed in Mineral Oil")
    case P3 : (Z14 thru Z41)
    g.drawString (" fault in Power Apparatus immersed in Nonmineral Oil")
    case P4 : (Z42 thru Z45)
    g.drawString (" low temperature fault in Power Transformer immersed in  Mineral Oil")
    case P5 : (Z46 thru Z50)
     g.drawString ("low temperature fault in Power Transformer immersed in Mineral Oil with different sets of
                    Gases")
     case P6 : (Z51 thru Z54)
     g.drawString (" low temperature faults in FR3  Oil")
     case P7 : (Z55 thru Z58)
     g.drawString ("low temperature faults in FR3 oil with different sets of Gases")
     Default:  Read (r ,fault1,fault2)

      If (M,N,H,I,J,K)  on (Z1-Z58) boundary lines, g.drawCircle(c,r)   (*C is M,N,H,J,K*)

      Compute max(fault1,fault2)

7.[Finished]

   Exit.
```

4. RESULTS AND DISCUSSION

Java provides facilities to the programmer to define a set of objects and a set of operations (methods) to operate on that objects. All types of data are declared as per standard syntax of java. On compilation of the Algorithm Hexagon shown in Section 3.1, the results are visually presented.

The software for interpreting the faults in transformers is designed in java platform by developing a Hexagon where all the faults are interpreted. This algorithm provides more flexibility in diagnosing the faults occurring in PT, LTC and PA immersed in mineral and non mineral liquids. This software is designed in such a way that data obtained from DGA for various PA which differ in insulation media employed in them can be used for importing input at an instant of time. The results obtained for few sets of data samples listed in Table 2 are presented in Fig.4.The dots display the interpretation of the faults inside the respective zones.

Table 2. Data Samples from Power Transformer Date of Commissioning: 08.11.2005

HC Values in ppm 16 MVA,110/11kV	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO_2	CO	Remarks By Lab Expert
Sample I-03.01.2006	46	168	37	286	2	840	-	Thermal Fault of above 100^0C Due to Overheating
Sample II-17.01.2006	64	224	49	376	2	1164	-	
Sample III-06.02.2006	38	219	52	377	1	1340	-	
Sample IV-16.03.2006	29	189	75	353	2	1454	-	
Sample V-11.04.2008	14	67	42	111	0	1223	-	Resample
Sample VI-07.08.2008	22	94	43	138	3	1823	-	
SampleVII-27.04.2009	25	96	50	158	6	1964	-	Satisfactory

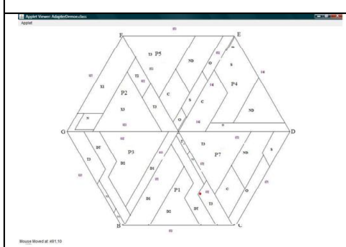
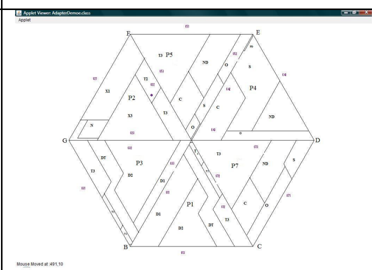
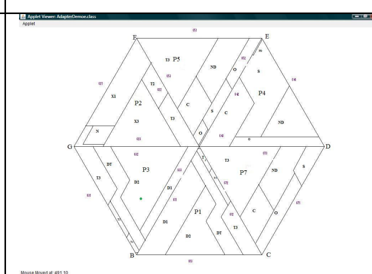
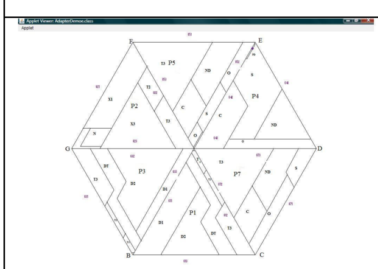
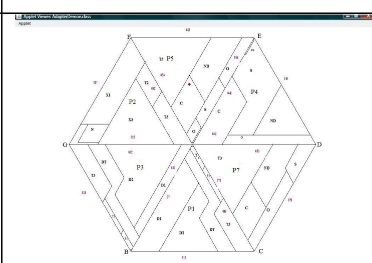
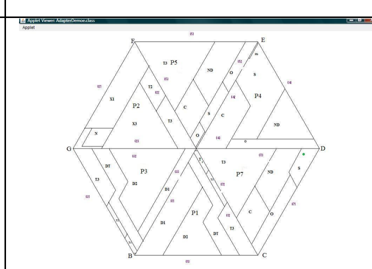
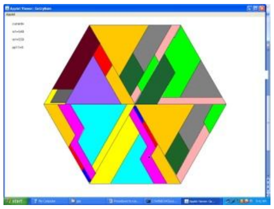
1. CH_4,C_2H_4,C_2H_2[14]	2. CH_4 , C_2H_4 , C_2H_2 [13]	3. CH_4,C_2H_4,C_2H_2[16]
		
Polygon P1 Fault in Zone T3	Polygon P2 Fault in Zone T2	Polygon P3 Fault in Zone D2
4. H_2,CH_4,C_2H_6[14]	5. CH_4,C_2H_4,C_2H_6[15]	6. CH_4,C_2H_4,C_2H_6[13]
		
Polygon P4 Fault in Zone PD	Polygon P5Fault in Zone C	Polygon P7 Fault in Zone S

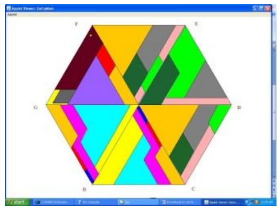
FIG.4. (a) Presentation of the results for sample datasets in ppm

1. CH_4,C_2H_4,C_2H_2[14]



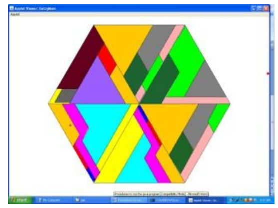
Polygon 1 Zone DT Thermal and Electrical Fault in PT

2. CH_4 , C_2H_4 , C_2H_2 [13]



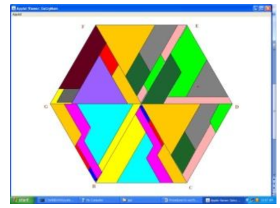
Polygon 2 ZoneX1 Thermal Fault in progress in LTC

3. CH_4,C_2H_4,C_2H_2[16]



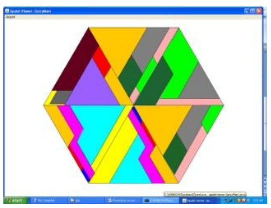
Polygon 3 ZoneT3 Thermal Fault T>700^0C for non mineral

4. H_2,CH_4,C_2H_6[14]



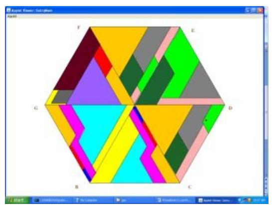
Polygon 4 Zone ND Non Deterministic

5. CH_4,C_2H_4,C_2H_6[15]



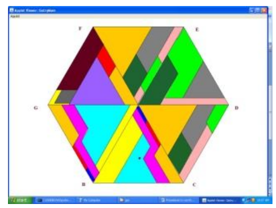
Polygon 5 Zone C Hotspots T > 300^0C in PT in mineral oil

6. CH_4,C_2H_4,C_2H_6[13]



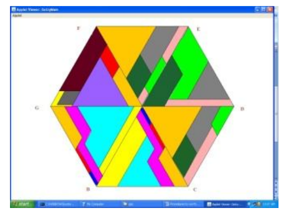
Polygon 7 Zone S Stray Gassing in FR3 oil

7. CH_4,C_2H_4,C_2H_2[14]



Polygon 1 Zone D2 Discharges of high energy

8.H_2, CH_4, C_2H_6 [15]



Polygon 6 Zone PD Corona Partial Discharges

FIG.4. (b) Visual Presentation of the results for sample datasets in ppm

5. CONCLUSION

This being a software implementation gives a visual picture of the indication of type of fault and user friendly modules and warns the Control Engineer to be caucious to protect the environment before failure takes place by analyzing the severety behind the shifting of the fault from less severe thermal into more severe electrical one.The effectiveness of the Hexagon Program is verified by DGA data collected from Oil Testing Centres in South India and the non mineral liquid data [13-16]. The probability of failure of a transformer due to fault in service can be determined by the studies made on the actual fault data reports obtained from the Electricity Boards Oil testing Centres in addition to this Interpretation. The Future work is to employ clustering algorithms for grouping the data sets.

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