Universal Fault Gas Triangle for Transformer Diagnostics

E. Bräsel, GATRON GmbH, Germany

Abstract

A new efficient tool, the universal fault gas triangle (FGT) with the coordinates hydrogen, acetylene and sum of the hydrocarbons for the transformer diagnostics, is presented. On the basis of selected application cases the conformity of the diagnostic results will be shown by the application of the FGT, based on the visualisation of the IEC 60599, with the determined types of fault based on the basic gas quotients.

Introduction

IEC 60599 describes transformer diagnostics on the basis of DGA. The study of several years of statistics of gas chromatographic laboratory analyses with 5 (H_2, CH_4, C_2H_2, C_2H_4, C_2H_6) or 7 (additionally C_3H_6, C_3H_8) fault gases has led to value ranges for three quotients dependent on types of fault. The practical application with the help of DGA interpretation tables for the determination of the six types of fault is supported by diagrams showing these quotients. What is visually more interesting is the Duval triangle [1] which is also listed and uses a diagram of the fault gases CH_4, C_2H_2 and C_2H_4 that is transformed to 100%, thus using the different energy densities of formation for diagnostics. The triangle can be used directly in its visual form and shows that diagnostics is also possible with three fault gases only. In practice, this can lead to diagnostic problems, e.g. in case of partial discharge and of leakages in OLTC vessels. The reason is that hydrogen in not included.

The aim of this paper is to demonstrate a visualisation area for the complete fault gas part in transformer gases dissolved as well as undissolved.

Diagnostics with the universal fault gas triangle

A new, powerful tool for diagnostics has been developed. It is based on the assignment of the gases to the main fault types:

H_2 – partial discharge
C_2H_2 – electrical discharge
CH_4+ – thermal fault

Here CH_4+ is the newly introduced parameter "monitoring sum of hydrocarbons". It is the weighted sum of the hydrocarbons CH_4, C_2H_6, C_3H_8, C_2H_4 and C_3H_6.This sum can be measured directly with a sensor or calculated from a full analysis. Using the three dominant fault gases of the main fault types allows the fault gas triangle (FGT) shown in Fig. 1 to be created.

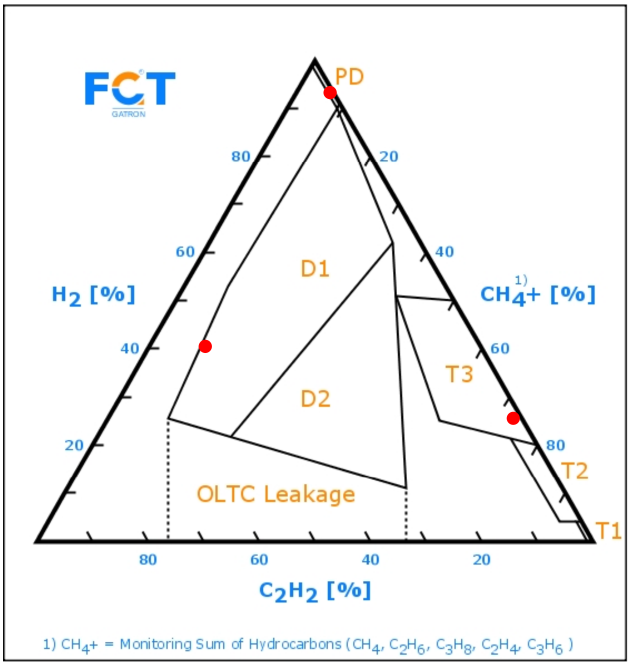

Fig. 1 Fault Gas Triangle for diagnostics according to IEC 60599
• diagnostic point of the application case

The result is a closed diagram which includes all fault gases. For the practical application of the gas triangle, it makes no difference whether the monitoring sum is measured with a sensor or calculated with the help of laboratory analyses. The concentrations of CH_4+, H_2 and C_2H_2 are transformed to 100% and then the registration in the fault gas triangle made. The conditions of use are the ones laid down in the standard: typical concentration values of the fault gases, additionally online CH_4+ > 200 ppm and the gas production rates known. For free gases of the Buchholz relay, it is necessary to use a modified procedure: first they are tested in terms of the equilibrium criterion, then they are corrected to the original composition on the fault location [2] and finally the CH_4 + content is calculated from them. For diagnoses it is necessary to visualise the fault types. This can be done using the diagnostic schemes (IEC 60599, MSS, Rogers, etc.) known. The marked areas in the fault gas triangle in Fig. 1 were calculated for the six fault types from the value ranges of IEC 60599.

Practical application

The selected application cases are monitored online with the Transformer Gas Monitor (TGM) or manual on basis of laboratory analyses sampling and extracting with the Extraction Gas Sampler (EGS-Method). Both GATRON products have the quality label N_2IS based!® [3].

In practice three different diagnostic variants are used:

- online diagnostics
- online based laboratory diagnostics
- short periodical laboratory analyses

In following an example for each variant is descript.

1. Suspect industrial transformer (60 MVA, 110/21 kV)

The transformer has had in a routine laboratory analysis higher concentrations of ethen and propen. For clearing up the situation a TGM-D mobile was installed on 04.07.2008. In Fig. 2 the monitoring diagram for the online diagnostics is shown. All gases for evaluating on basis of IEC 60599 are seen.

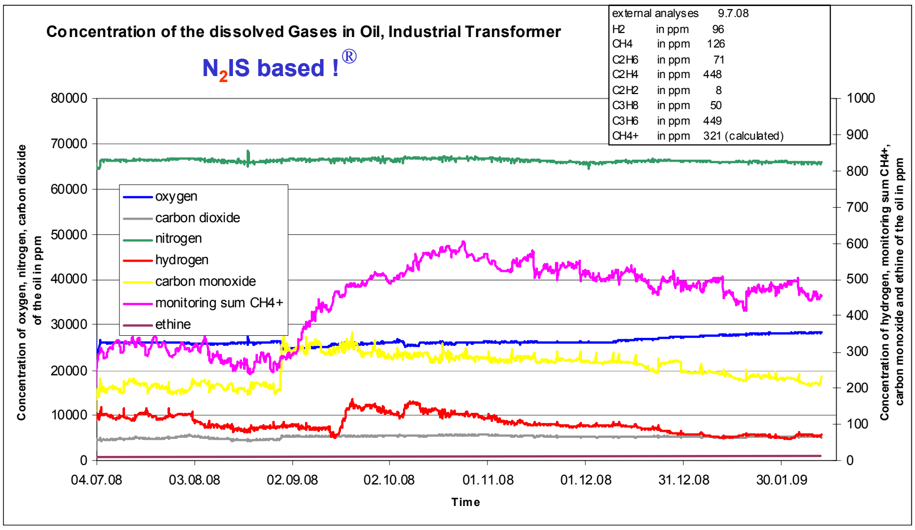

Fig. 2 Operating diagram for the online diagnostics (TGM-D)

The oil is saturated with air and has only a small deficit of oxygen. The hight of the both carbon oxid concentrations and their relation don't show a higher degradation of the solid insolation. The monitoring sum of the hydrocarbons CH_4+ is a little higher on the beginning, but relative constant. It begins to increase significantly on the 02.09.2008, later for nearly one week the hydrogen concentration also. On the 20.09.2008 the following fault gas concentrations with the TGM-D were measured (nearly values): CH_4+ 500 ppm, H_2 180 ppm, C_2H_2 10 ppm. The transfer in the FGT produces the diagnostic point 1 in Fig. 1 and means the fault type T3. An after installation leaded external laboratory analysis (EGS method), the results are fixed in the window of Fig. 2, is identical with the online values. The evaluation with the quotient criterion of IEC 60599 or with the Duval triangle has the same result: fault type T3.

With the online monitoring it is possible to have more information: in the time from 2 to 14.09.2008 the starting period of the fault without the production of hydrogen is visible, this means with lower energy density (T1 or T2). From 22.09.2008 the fault is not more active. The hydrogen concentration is decreased till to the starting value, this is typical for open type transformers. The reason of the fault is a defect contact within selector switch. It is very important, only in the current situation of the fault to determine the type of fault. In the other case the diagnose is not correct.

2. Suspect grid transformer (333 MVA, 400/220 kV).

In the routine laboratory analysis high hydrogen concentrations were established. The evaluating with the quotient criterion of IEC 60599 had have the result partial discharge PD. With Duval triangle it was not possible to distinguish between PD and T1.

On the transformer a small online monitoring variant (H_2, O_2, CO_2, N_2) was started. The monitoring diagram is shown in Fig. 3. It is visible that the oil is on the end of the resaturation phase, without oxygen deficit. The carbon dioxid concentration is not significant. There the hydrogen concentration is increased continually the fault is current.

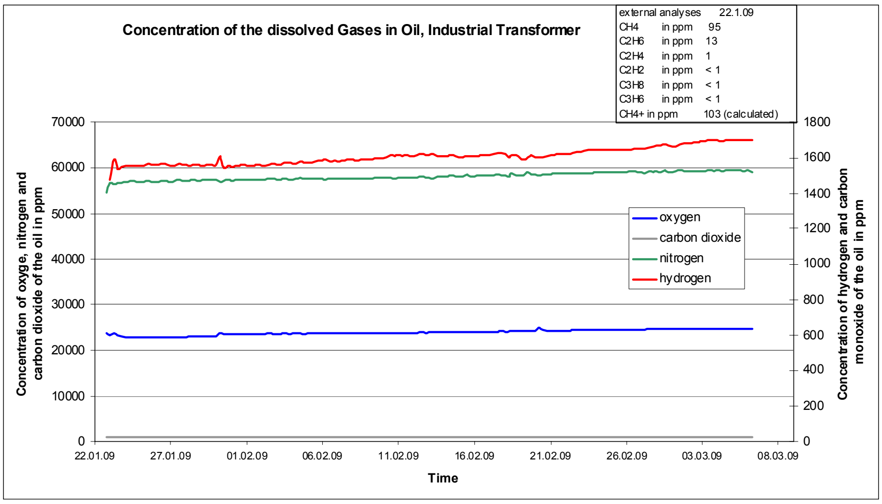

Fig. 3 Operating diagram for the small online monitoring

The EGS analysis on 22.01.2009 shows identical results to the online values (window in Fig. 3). The calculated monitoring sum of hydrocarbons has the value 103 ppm. Together with the hydrogen (1450 ppm) and acetylene (<1 ppm) concentration the diagnostic point 2 in the FGT (Fig. 1) is given. The fault type is PD. With the online hydrogen concentration time slope it is possible the actuality or the changing of the fault type to monitor.

3. Suspect grid transformer (20 MVA, 110/20 kV) .

Two successive routine laboratory analyses have shown a clear ascent of hydrogen and acetylene concentrations. Repetitions of laboratory analyses confirmed the actuality the of fault (Tab 1).

Sample from	15.02.08	07.08.08	11.09.08	08.01.09	21.04.09	14.05.09
Oil temperature [°C]	5	30	25	20	36	32
Sampling point	under	under	under	under	under	under
Gases [ppm]:						
H_2	39	124	102	179	285	298
O_2	31052	31151	26717	26815	30100	28699
N_2	69295	68652	65982	64749	65309	68175
CO	65	178	169	132	126	132
CO_2	1694	2457	2362	2214	2550	2451
CH_4	5	15	15	34	45	48
C_2H_6	<1	3	<1	7	10	11
C_2H_4	4	15	15	32	49	52
C_2H_2	45	174	164	225	298	302
C_3h_8	<1	<1	<1	9	<1	<1
C_3H_6	<1	3	<1	3	<1	4
Total gas content [%]	9,43	10,52	9,79	9,67	10,11	10,41
Solution pressure [mbar]	929	1047	985	972	1003	1044

Tab. 1 DGA for the laboratory diagnostics EGS method N_2IS based ®

For the 14.05.2009 the calculated monitoring sum is 55 ppm. Together with the hydrogen (298 ppm) and acetylene (302 ppm) concentrations the diagnostic point 3 in the FGT (Fig. 1) is given. The fault type is the discharge at low energy D1. All other analyses confirm this. Also the evaluating with the quotient scheme of IEC 60599 or Duval triangle have the same result.

Conclusions

The selected application cases show that by using quality secured analytical data and the proof of the actuality of the fault the universal fault gas triangle and the diagnostic criteria of IEC 60599 deliver complete identical diagnostic results. The application of the universal fault gas triangle enables reduced costs for the online diagnostics. This is possible with new developed sensors for acetylene and for the monitoring sum of the rest of hydrocarbons C_1 – C_3 instead of all hydrocarbons to determine individual. Technical tenders should accepted this than the aim is to differentiate six fault types.

But the application cases show also that in difference to the permanent task of monitoring the diagnostics is only applicable in current fault situations. The transformer personal can select from the presented diagnostic variants the optimal solution for the concrete case.

Literature

[1] Duval, et al., CIGRE Symposium Berlin 1993, Paper 110-14

[2] Bräsel, E.; Brunner, E.; Hartmann, E.
Neue Hilfsmittel zur Diagnoseeignung von Gasen aus dem Buchholz-Relais
Elektrizitätswirtschaft H25, pp. 16-24, (1999)

[3] Bräsel, E., Sasum, U.; Online Transformer Gas Diagnostics on the Basis of IEC 60567/60599, International Conference on Power Transformers Transformer 09, 89-93, 02.-04.06.2009,Torun, Poland