Verlassen Sie sich nicht auf Ihren Standard

Dipl.-Ing. (FH) Georg Daemisch

Daemisch Industriedienstleistungen GmbH

Education

- M.Sc.Electrical Power Engineering-Karlsruhe-Germany

Professional Career

- DTC (Daemisch Transformer Consult) specialized in consulting for transformers and executing On-Line treatment of transformers and life time assessments – 2005 until now
- Owner and managing director of DIDEE GmbH (Daemisch Industriedienstleistungen GmbH) and – 1992 until now
- Independent – 1991
- Ginsbury Electronic – 1988
- Sales Engineer for southern Europe in MR (Maschinenfabrik Reinhausen) in Regensburg/Germany for OLTC's – 1985
- Sales Engineer for big power transformers in BBC Mannheim (ABB) for Latin America, Near East and other areas – 1978
- Sales Engineer for small and middle sized transformers in TRAFO UNION (Siemens/AEG) – 1975

Verlassen Sie sich nicht auf Ihren Standard

Introduction:

Standards were developed as early as the late 19th Century for the purpose of harmonizing the properties of certain products and processes and thus rendering them comparable. Specific dimensions and technical properties are defined in accordance with the specifics of a standard. Needless to say that the world of transformers is equally governed by standards, and that without a doubt, much effort has been invested in the creation of viable guidelines and principles useful for the various different applications.
Without a doubt, a general distinction can be made between two fundamentally different types of standards:

- Standards created to define a specific design or technical feature
- Standards created to facilitate or define the evaluation of data

In the world of transformers, both types of standards have their established place. It could be said that one type of standards represents the "hard standards" established to specify particular data and features in a mandatory and measurable manner. Whereas the other type of standards is based on empirical values gained by experience which may not be measurable in every single case. In many cases, the answers provided in such documents may be somewhat vague or relative and may therefore be valid only under certain marginal conditions. Especially where the evaluation of data from DGA and oil testing is concerned, to focus tends to be rather on the "soft" side. That is why there is a huge margin for interpretation - especially what with the collision of two fundamentally different worlds and philosophies, i.e. the world of IEC and the world of IEEE. And it takes a due and careful account of these fundamentally different ways of thinking and working to allow for a reasonably comparability and joint application. However, background efforts must be made at all times to comply with the general physical rules.

It is of the essence to take into account two radically different approaches:

- The world of IEEE is based in virtually every case on closed (sealed) systems (with airbags or similar).
- The data, values, and limit values of the world of IEEE are in all cases based on experience. Data, which, no matter how very local and specific they may be, are nonetheless generally considered as globally applicable.
- By contrast, experience in the world of IEC is essentially based on open breathing systems.
- The world of IEC is based in a reproducible scientific background.

What also happens, however, is that assumptions are made and introduced to the European standards which would without a doubt have benefitted from scientific analysis and backing.
As a result, a very wide "soft" area remains in either case where the scope of interpretation remains equally wide and where the results do not always dovetail with reality, or where - in cases where the results actually to dovetail with reality - it is an expert's experience or even intuition which is sought after, rather than hard reproducible facts.
Needless to say, many experts like to benefit from the fact that their results are often not reproducible as computer programs, a fact which attests to the experts' indispensability on the one hand, while on the other hand it must surely be unsatisfactory to be unable to prove one's results on the basis of unambiguous facts.
This task is made even more difficult in cases where it becomes necessary to forsake the printed standard when it fails to truly cover the case at hand. In some countries especially, there is a tendency towards "orthodoxy", which makes it difficult to get people to realize that healthy common sense should override blind faith in the printed matter.

Verlassen Sie sich nicht auf Ihren Standard

1. IEC 10/907CD:2013:
This standard serves as guideline for assessing the interpretation of DGA results and is currently undergoing an updating phase. This would have been an excellent opportunity for introducing some fundamental amendments. One of the big issues is to make a distinction between gas contents and gas production. Logically, gas content is the result of gas production and gas loss. It is not always easy to establish the link between gas production and gas content. Taking a look at the resaturation curves established with the aid of online technology makes it obvious that the gas exchange between tank and atmosphere can be highly different from one case to the next.

The assumption made in Article §6 "Explanatory notes", according to which gas losses occur only from slow diffusion and temperature cycles and are therefore supposedly negligible, can most certainly not be maintained. Notably in open breathing transformers, the gas exchange with the atmosphere depends to a large extent on a very wide variety of different factors and may, according to Gatron's measurements, be larger by a factor of 1/10 or higher. A relatively seamless transition to the open transformer types is achieved only by the inadequately hermetically sealed transformer types whose gas exchange comes relatively close to that of badly breathing open transformer types. As a consequence, open transformer types often show resaturation times (N_2) anywhere between several weeks and up to approx. six (6) months; next in line are the badly hermetically sealed transformer types which show resaturation times of up to several years.

Resaturation N_2 represents the optimum indicator for this process as no nitrogen is consumed for any of the processes and can therefore follow only an upward trend until the point of saturation. Typically, saturated systems should yield a measurement of approx. 80,000 ppm N_2. Regrettably, correct nitrogen measurement appears to present a problem to some extent, making it difficult to truly categorize this clear indicator and hence the entire measurement of gas content and gas production. In cases where the content N_2 of measurements decreases as a result (without a degassing treatment having taken place), there is reason to suspect that the other gas contents are also being understated and that any statements about their development are unreliable as a result.

When taking a look at the ranges of the "typical" values, "concentration values", "gas formation values", "limit values", one cannot help but feel bewildered when trying to obtain a reliable evaluation from these values. Especially in cases where a mix of standards results in the introduction of data from the world of IEEE whose plausibility (such as e.g. N_2 max = 115,000 ppm) still requires a great deal of discussion, to say the least.

2. IEC 60422

This standard has since its first inception suffered from the misconception that the values under consideration are supposedly oil values and are therefore liable to improvement by actions pertaining to oil. In actual fact, however, it is only the acid value and interfacial surface tension of tan δ in the limits and thresholds which concern the oil quality. All other values such as breakdown voltage and water content are transformer values which are reflected in the oil. This fundamental misunderstanding may also have given rise to the misconception that the issue of water content in transformers is still an unsolved problem. It is true that the "corrected water content" has in the meantime been abandoned (unfortunately this procedure continues to be in use, often without being declared as such, making it ultimately impossible to assign that value) in favor of and replaced by the relative humidity value (RH) adopted from the IEEE. However, due to the lack of a confirmable relationship between the relative humidity of the paper and the absolute humidity in %, this is of no great help either. Application of the figures proposed, results in the conclusion that 3.7% of water in the cellulose is a "fair" value. However, as the technical literature has long judged values of more than 2% as unfavorable due to their leading to accelerated aging of the paper, these figures appear to be of equally limited use.

This is exacerbated by the fact that the actual water content depends to a large extent on the degree of aging (aged paper tends to store less water) and the design (modern transformers have often been designed to contain very little paper). In many cases, water content can be gauged only by an extracting treatment. Even direct-measuring dielectric methods are often less than helpful, particularly in cases where they are used in combination with the PCD method which typically yields excessively high values.

As indicated earlier under Chapter "2", the meaningful assessment of data without the appropriate background knowledge is virtually impossible.

3. Exchange mechanisms:

The assumption that exchange occurs mainly through "slow" adoption diffusion is relatively easy to disprove by taking a look at the hydraulic background. As a general rule, gas exchange depends on the following factors:

- Open or closed design.

- Connection between tank and oil conservator.

- Oil conservator design (round, flat, railway profiled, several)

- Transformer location (indoor/outdoor/cardinal direction)

- Load profile.

Background: The oil conservator simultaneously serves as a cooler, resulting in the ongoing circulation of the tank oil through the oil conservator. Calculations have shown that the tank oil may be guided through the oil conservator up to six (6) times per day. It thus happens that in vessels with a very large inside surface, such as the railway profiled oil conservator, the gas exchange turns rate is way above the straightforward diffusion rates. Since it is obviously the temperature difference which drives the thermo-syphon flow, the influence of factors such as load, heat dissipation (outdoor), and external heating from exposure to direct sunlight is very high: This is the underlying cause for the known differences in gas content during the winter and summer months.

The water content in transformers is influenced mainly by "moisture bridges" in the sealing system. In most cases, the pyrolysis effect tends to be overestimated.

4. The purpose behind these considerations:

You may naturally wonder why it should be necessary to delve so deeply into the background and to render such seemingly simple applications much more complex by raising a lot of doubts.

When perusing e.g. IEC 10/907, you will find that this is all about one issue and one issue only: failure identification. Under current circumstances, however, the application of these tools should go a whole lot further. Today's situation is characterized by an extremely overaged inventory on the one hand and new "smart" designs on the other hand whose short- to medium-term reliability is anything but free of doubt. This makes the task of "condition assessment" ever more important and ever more complex. The issue simply cannot be put to rest by a simple "OK" or "Faulty"! It is important to distinguish between three different conditions:

- A = indication free: no problems or failures displays

- B = indications found: i.e. "not in perfect health" but no failure condition found

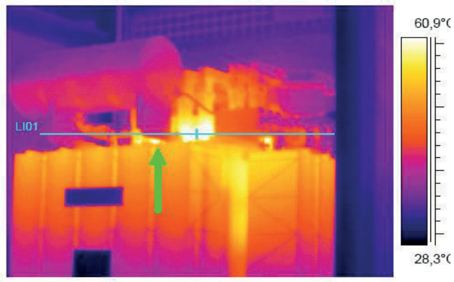
- C = faulty

The most important condition for our considerations is case "B", which is about remaining lifetime assessment (better termed as remaining substance assessment), risk assessment, and population management.

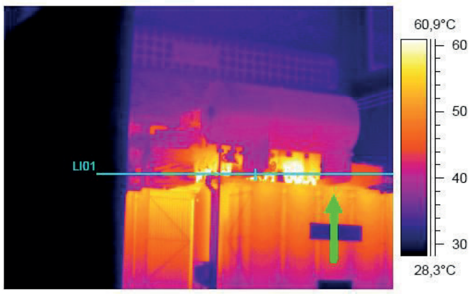
Accomplishing these tasks requires both reliable data and the correct and knowledgeable evaluation thereof. And here is where the standards come in: To provide the appropriate instructions. This task will certainly not be accomplished by simplified practices, or by going along with the current trend of altogether disregarding the atmospheric gases, or worse yet, by relying on fault gas quotients only. And if worst comes to worst and simple traffic-light assessment concepts are used, a total misjudgment and incorrect risk evaluation may be the inevitable consequence. If, for example, a transformer is assessed as "green" because the BDV equals 31 kV while the identical transformer in parallel is assessed as "red" at 29 kV, we are looking at a dangerous misjudgment because a holistic view would show us that both transformers are in critical condition and that the power supply from this substation is in imminent danger of failure.

5. Examples, pictures, graphics:

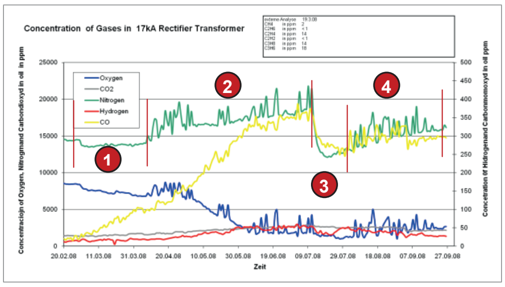
Thermo-syphon flow through the oil conservator



The image above shows a transformer in a standard design, the connection tube to BHR is filled with warm oil, as is the oil conservator.



In the following image, the connection of the oil conservator was relocated to the transformer's inactive bottom sump; the thermo-syphon flow comes to a standstill and the transformer nearly exhibits the behavior of a closed system even though the oil level in the oil conservator continues to be remain open to the atmosphere and hence to diffusion.



Transformer during partial degassing 1 ; deactivation of partial degassing and switch-over to changed oil-conservator connection 2 ; partial degassing connected 3 ; partial degassing deactivated 4 .

The above evaluation shows the distinctly different behavior for the various different "design conditions".

- After connection of the "barrier" there is a decrease of O_2 as a result of the consumption within the system, with a commensurate increase of CO and CO_2. During continuous operation, there is a slow saturation of N_2 commensurate with the reduction in availability whereas O_2 is reduced to a minimum. CO remains relatively high as its loss is now hindered by the barrier even though the available O_2 remains at an equally reduced level.

Measured curves

The graphs established by Gatron have been inserted to serves as background

Verlassen Sie sich nicht auf Ihren Standard

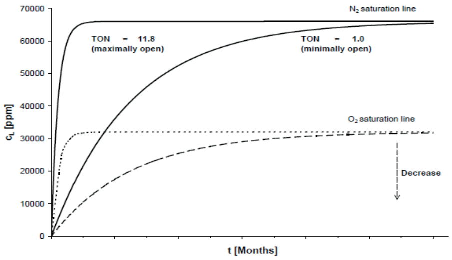


Fig. 2 The resaturation slopes of open type transformers

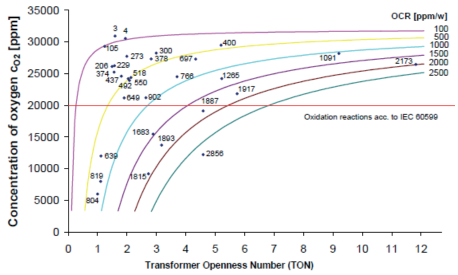


Fig. 3 Oxygen Consumption Rates (OCR) of investigated transformers

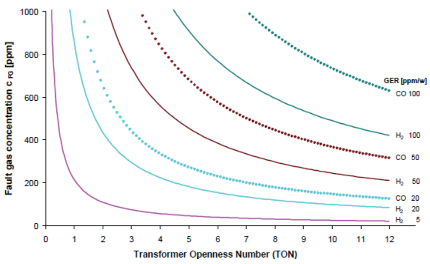


Fig. 4 First approach for Gas Emission Rates (GER)

CO/CO2 ratio

The data represented below lead to a lot of excitement on the transformer users' as the laboratory warned against a thermal failure with paper involved due to "increased" CO values. Simply because the CO value had exceeded the critical value of 570 ppm stated in the IEEE. The laboratory measurement may generally be questioned when considering the values of N_2 and O_2, especially since the transformer is equipped with a closed oil conservator (air bag). In cases where this system is relatively leaky, the available oxygen may also be higher, as may be the production of CO depending on the load. As a general rule, the CO value represents the temperature conditions within the transformer; this means that the transformer will at all times be relatively warm, if only due to the transformer's high ambient temperature. Since none of the other data provide any indications whatsoever, the CO value may in this case be rated as insignificant even though some standards would be speaking of a critical value.

DISSOLVED GAS ANALYSIS (ASTM D3612), EXPRESSED IN PPM

DATE	HYDROGEN	OXYGEN	NITROGEN	METHANE	CARBON MONOXIDE	CARBON DIOXIDE	ETHANE	ETHYLENE	ACETYLENE	TOTAL COMBUSTIBLE	TOTAL GAS
08/07/2011	24	22965	48382	6	587	1219	ND	2	ND	619	73185
06/01/2012	18	22636	51129	7	659	1324	ND	2	ND	686	75775
19/04/2012	16	20019	91250	6	614	1171	ND	1	ND	637	113077

NO.	PARAMETER	HASIL UJI (ppm)	BATASAN TDCG IEEE std C57.104-1991	
1	Hydrogen (H_2)	0.0000	100	**0 - 720 ppm** : Indikasi Operasi Trafo Normal **721 - 1920 ppm** : Indikasi terjadi sedikit dekomposisi dari sistem isolasi trafo **1921 - 4630 ppm** : Indikasi terjadi dekomposisi tingkat tinggi sistem isolasi trafo **> 4630 ppm** : Indikasi terjadi banyak dekomposisi dari sistem isolasi trafo
2	Oxygen (O_2) (*)	64,207.0000	2,586.000	
3	Nytrogen (N_2) (*)	77,953.0000	155,843.000	
4	Methane (CH_4)	3.6310	120	
5	Carbon Monoxyde (CO)	105.9600	350	
6	Carbon Dioxyde (CO_2) (*)	1,072.4340	2,500	**(*) Catatan :**
7	Ethylene (C_2H_4)	12.3940	50	Gas Oxygen (O2), Nitrogen (N2), dan Carbon Dioxyde (CO2), Propane/Prophylene (C3H8/C3H6) tidak termasuk dalam kategori gas - gas yang mudah terbakar (Combustible Gases)
8	Ethane (C_2H_5)	0.0000	65	
9	Acetylene (C_2H_2)	0.0000	35	Jadi gas-gas O2, N2, dan CO2, C3H8/C3H6 tidak dihitung pada hasil jumlah TDCG (Total Dissolved Combustible Gases).
10	Propane / Propylene (C3H8/C3H6) (*)	0.0000	440	
	JUMLAH (TDCG)	121.9850	720	
	TOTAL GAS	143,354.4190		

Kesimpulan :
Berdasarkan standard IEEE std C57.104-1991, hasil TDCG dalam minyak trafo tersebut diatas dinyatakan :
Indikasi Operasi Trafo Normal

Data evaluation by a laboratory

When considering the above image, it can be safely stated that the normal limit values mentioned earlier make little sense, that the value for N_2 is entirely meaningless, and that the value for O_2 makes sense only for closed transformers at the most. The case at hand, however, deals with an open breathing transformer. In this case, the "normal value" would in any case have to be >20,000 ppm. The measured values are incorrect, the O_2 value is nonsense. During that period, the transformer was running with partial degassing, which resulted in the following correct and logically confirmable figures.

Dissolved Gas Analysis (DIN EN 60567)	
- Hydrogen	<10 ppm
- Oxygen	2500 ppm
- Nitrogen	14939 ppm
- Carbon monoxide	143 ppm
- Carbon dioxide	2156 ppm
- Methane	2 ppm
- Ethane	<1 ppm
- Ethylene	23 ppm
- Acetylene	<1 ppm
- Propane	<1 ppm
- Propylene	10 ppm
- Total Gas Content	2,03 Vol %
- Solution pressure (calculated)	202 mbar

The expression "combustible gas" is often misinterpreted to the effect that a "combustible mixture" might develop inside a transformer which needs to be counteracted by periodic degassing.

Example of a grid coupler:

A 220/110 kV interbus coupler has about 20 ppm acetylene and 100-200 ppm hydrogen.

The lab interprets this data as harmless: "The C_2H_2 comes from the leaking diverter switch and the H_2 is accumulated due to low exchange with the atmosphere".

O_2 (24119 ppm) and N_2 (67 442) data, = high

the real gas production of H2 and C2H2 is much higher

The OLTC is operated very seldom (once a week) and therefore the production of the switching gases is very low.

Finally, the identical twin, which had even lower values, had failed due to an interturn fault. It is very dangerous to trust to such interpretations.

The final balance of gas content is always the result of production and loss to the atmosphere.

6. Summary

The development in the field of transformers demands a new understanding of the traditional monitoring data to permit a viable solution to the current problems. The former emphasis on the benefits of DGA and oil testing for fault identification has in the meantime made way to the necessity of establishing a condition assessment for the users' medium- and long-term planning. Even the option of a load capability analysis, in combination with a risk assessment, has become indispensable for system reliability and for cost minimization. This also includes the more finely honed detectability of conditions, which in turn necessitates a more in-depth understanding of the background. A simplistic black-and-white or red-and-green approach cannot possibly to justice to these demands. Needless to say, this situation also needs to be taken into account in the realm of standardization, especially since experience-based expertise is increasingly based on "clay feet" as the older experts are increasingly working towards a biological solution.

Verlassen Sie sich nicht auf Ihren Standard

July 2014

DTC – Daemisch Transformer Consult
Georg Daemisch
Alte Nürnberger Straße 32a
93055 Regensburg
Tel.: +49 (0) 941 87867
Email: daemisch@didee.de

Education
M.Sc. in Electrical Power Engineering, Karlsruhe, Germany

Professional Career

- DTC (Daemisch Transformer Consult) specialized in consulting for transformers and performing online treatment of transformers and life time assessments – 2005 until now
- Owner and managing director of DIDEE GmbH (Daemisch Industriedienstleistungen GmbH) – 1992 until now
- Self-employed – 1991
- Ginsbury Electronic – 1988
- Sales Engineer for Southern Europe for MR (Maschinenfabrik Reinhausen) in Regensburg/Germany for OLTC's – 1985
- Sales Engineer for big power transformers for BBC Mannheim (ABB) for Latin America, the Near East and other areas – 1978
- Sales Engineer for small- and medium-sized transformers for TRAFO UNION (Siemens/AEG) – 1975