The Extension of IEC 60599 to Open Type Transformers

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Question 2-1: What is the best way to increase the efficiency of interpretation algorithms ?

It is well accepted all over the world that transformer diagnostics is based on the gases dissolved in oil. The standard used for evaluation, IEC 60599, is written for closed transformers. The influence of openness is assumed to be negligible. Only in an annotation is it mentioned that some experts think that the transformer types should be differentiated. However, practical steps are missing. To this very day, all practical diagnoses have been made without considering any differences to open type transformers. Time has come to solve the openness problem for the transformer type applied the most widely around the world with the help of online multi-gas monitoring. Openness also requires the role of oxygen in transformers to be clarified.

Fig.1 shows the alternative way according to IEC 60599 in the case of open type transformers. The atmospheric gases must be stronger represented. The inert gas nitrogen can be used for the determination of the transformer openness number (TON). This allows the oxygen consumption rate (OCR) to be calculated from the oxygen concentration. In the same way, it is possible to calculate the gas emission rates (GER) from stationary levels of hydrogen and carbon monoxide.

Many years of practical experience with the Transformer Gas Monitor (TGM) have enabled GATRON to find the solution: the resaturation slope of air nitrogen in degassed open type transformers. Depending on the design, the location and the basic operating type, different increases of the nitrogen slope were found. These are based on the physical processes of oil convection between tank and conservator as well as the gas exchange on the oil level in the conservator. The result is that resaturation times for air nitrogen vary from a few to many months.

Atmospheric gases (2)		Fault gases (9)	
N_2	O_2	CO, CO_2	H_2, CH_4, C_2H_2, C_2H_4, C_2H_6, C_3H_6, C_3H_8
		Solid Insulation	Oil
OPEN		CLOSED	
	- O_2/N_2 Limit	- Concentration Limits	- Emission Rates - Quotients

Extension: Quantification of openness

Transformer Openness Number (TON)	Oxygen Consumption Rate (OCR)	Additional: Gas Emission Rate (GER) for H_2 and CO

Fig. 1 Evaluation of transformer gases acc. to IEC 60599

It needs to be stressed that all data evaluated have accuracies of less than 8% based on a natural internal standard (N_2IS based!).

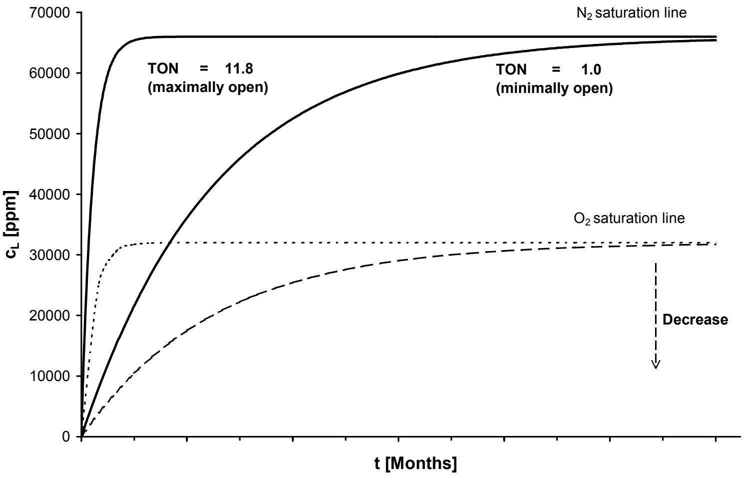

Fig. 2 The resaturation slopes of open type transformers

Fig. 2 shows the two extremes of the 29 transformers investigated. For practical purposes, it is better to define the TON as the quotient of the nitrogen increase in the transformer under investigation and the nitrogen increase in the transformer with the minimal increase. Thus, the TON values are between 1 and 11.8. In comparison to this, a TON of 0.01 is typical for a tight air bag transformer. Similar resaturation slopes are also found for oxygen. Both atmospheric gases reach their saturation concentrations according to the air-in-oil standard of IEC 60567.

In the case of oxygen, this is only possible for new transformers or older transformers showing no signs of aging of the insulating system. In practice, the oxygen concentration typically falls to less than the saturation concentration. This was the basis for GATRON to develop a method to determine the OCR as a measure for the sum of oxidation reactions.

Fig. 3 shows the OCRs of the investigated 29 transformers as a function of TON and oxygen concentration. Firstly, the distribution of the transformers over the TON range becomes visible.

The transformers with a cylindrical conservator are on the left side and the two transformers with a flat conservator are on the right side. Secondly, the OCR points calculated can be seen.

For better visualisation, there are some curves for the same OCR. So it is possible to see the point for the lowest OCR (new GSU transformer) and the highest OCR (stressed old industrial transformer). The condition for higher intensity of oxidation reaction according to IEC 60599 is the quotient O_2 / N_2 < 0.3. In the normal state of nitrogen saturation, this means an oxygen concentration of 20,000 ppm (the straight line in Fig. 3). Below this line there are OCRs of >500ppm/w for transformers which are more closed.

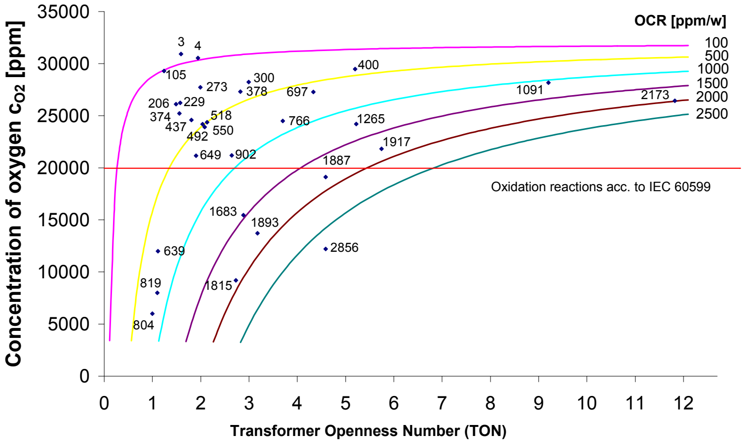

Fig. 3 Oxygen Consumption Rates (OCR) of investigated transformers

But the same situation is not considered for transformers which are more open. Therefore, the OCR is better suited for the quantification of the oxygen consumption. Additionally, an OCR of >500ppm/w can be used for clarifying the situation with the aim of post-installation hermetic sealing. This presents an alternative to installing a hermetic transformer from the beginning: to monitor the OCR with routine DGA and, if the OCR is >500ppm/w, hermetic activities to be started. In this way, the OCR means progress for open type transformers.

While atmospheric gases enter the tank, H_2 and CO with low solubility leave it. This requires the TON, too. On basis of single fault situations with suspect C_{FG} values and GER values determined after post-installation hermetic sealing, the approximate curves for H_2 and CO are obtained (Fig. 4). The lower curves for H_2 (5ppm/w) and CO (20 ppm/w) are the values for suspect transformers according to IEC 60599. This shows how important it is for diagnoses to know the TON of the transformer.

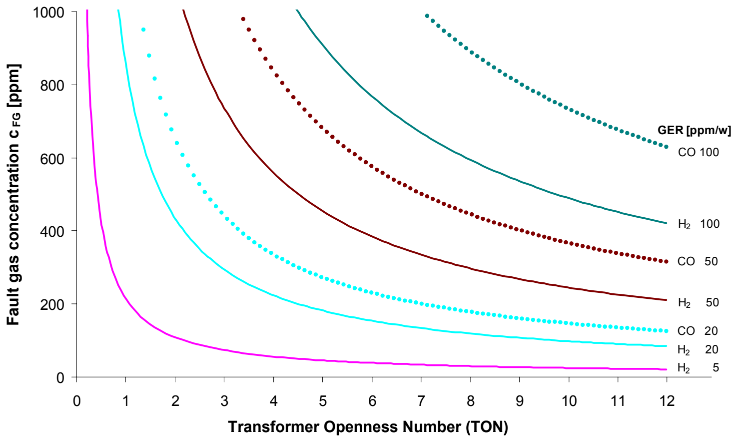

Fig. 4 First approach for Gas Emission Rates (GER)

For example, a measured H_2 concentration of 500 ppm may vary in GER between 5 to 100 ppm/w dependent on the openness of the transformer. Especially in the case of more open transformers, the intensity of partial discharge including the gas alarm risk as well as the type of fault determined through the quotients with better soluble fault gases can be evaluated correctly only on basis of the GER of H_2 only. CO plays a similar role for the evaluation of solid insulation. Only with TON correction is it possible to determine the presence and type of a fault.

The strategy for practical application should be using each degassing situation for a measuring of the resaturation slope. In the next few years, it is to be expected that statistics of the different features of transformer constructions and operating conditions as well as the respective resaturation slopes will enable the TON of transformers to be approximately predicted. For suspect transformers, it seems to be better to opt for post-installation hermetic sealing. The advantages are that the acceleration of aging through oxygen can be stopped immediately and that to the GERs of H_2 and CO can be measured directly.

For aging transformers, this is a good way to save cost and time for degassing with resaturation measuring and to invest the money saved in activities that can extend transformer life.