Improved evaluation of open type transformers according to IEC 60599

1. Starting situation

The norm for the interpretation of the analysis of dissolved and free gases is aimed at closed transformers. The differences between open and closed transformers are only small, so that uniform criteria apply, whose value ranges were defined without consideration of differences. A remark in Section 6.1 of course admits the influence of the open type construction, which then, according to the norm, affect all criteria. The desirable identification of possible influences of the open type construction requires its quantification.

2. Quantification of the open type construction

Many years of experience with TGM resaturation measurements after degassing give a detailed insight into the gas household. Fig. 1 shows the typical concentration slopes of selected gases till nitrogen saturation. The saturation concentration is nearly 66,000 ppm N_2 ± 10% and corresponds to the solubility of the nitrogen of the air, which means that the air composition is nearly given for the gas room of the conservator. The saturation concentration depends on the altitude of the transformer location as well as on the oil temperature. The time till the saturation is determined by the constructive features of the transformer, the installation conditions as well as the main operating regime. The N_2 concentration slope can described sufficiently accurately with an exponential function. So the inert gas nitrogen fulfils all prerequisites to enable the open type construction to be quantified.

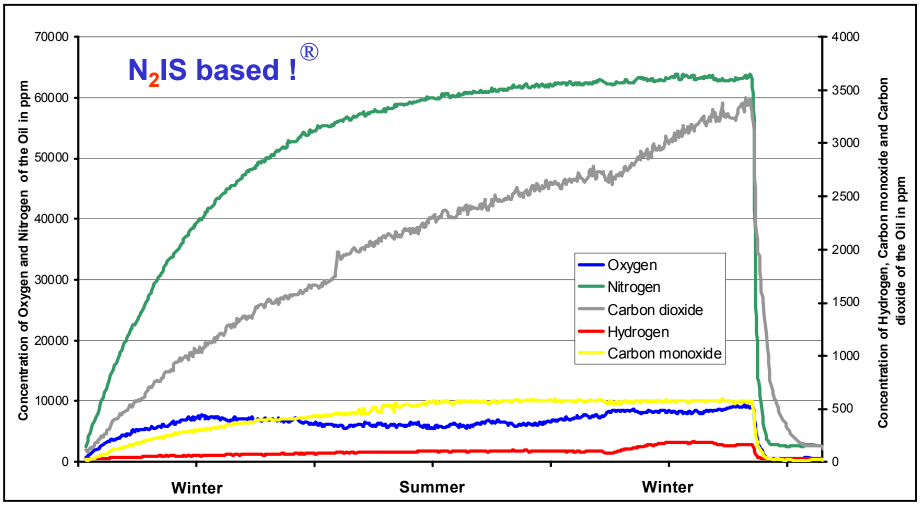

Fig. 1 Resaturation measurement on an open type transformer

In practice, very different resaturation times are measured. They are dependent on the starting N_2 emission rate. The standardisation of the rate for the transformer found to be the least open leads to the transformer openness number (TON), which represents a dimensionless measuring number for the quantification of the open type construction. It is individual and fundamental both for the transport of the atmospheric gases into the tank and for transport of the fault gases into the conservator. For the investigated transformers, the TONs vary from 1 (little open) to 9.2 (very open). In comparison to this, the TON for transformers with a tight air bag is nearly 0.01.
Transformer openness number allows the gas consumption or gas emission rates from stationary gas concentration levels to be determined.

3. Oxygen consumption (OCR)

Fig. 1 also shows the behaviour of oxygen. The concentration of the chemically active oxygen shows, in difference to nitrogen, dependencies on the aging state of the insulating system, which can lead to a significant decrease to less than the saturation concentration (nearly 32,000 ppm). Load/temperature changes are visible through reversible concentration changes (e.g. summer/winter) influences.

The oxygen decrease is checked in the norm with the help of the quotient $O_2/N_2 < 0.3$ (identical < 20,000 ppm O_2 as an orientation value) and evaluated (accelerated oxidation reaction). This reflects the balance between oxygen entry and consumption, the latter quantifies the oxidation reactions. The oxygen entry can be determined from the exponential function for nitrogen with the help of the difference between calculated saturation concentration and measured concentration of oxygen (c_{O2}). Fig. 2 shows the curves for the oxygen consumption (ppm O_2/week) determined OCR values for the investigated calculated on this basis as a function of TON and CO_2. The transformers are between 3 ppm O_2/w (new start) and 2860 ppm O_2/w (stressed industry transformer). The risk of raised OCR values (> 500 – 1000 ppm O_2/w) begins at c_{O2} < 28,000 ppm. In this case, it is recommended to make an accurate determination with the known TON.

For open type transformers, instead of an orientation value for the oxygen concentration, the oxygen consumption is used as an individual measure of the aging acceleration for the first time. This can be used for activities of substance conservation.

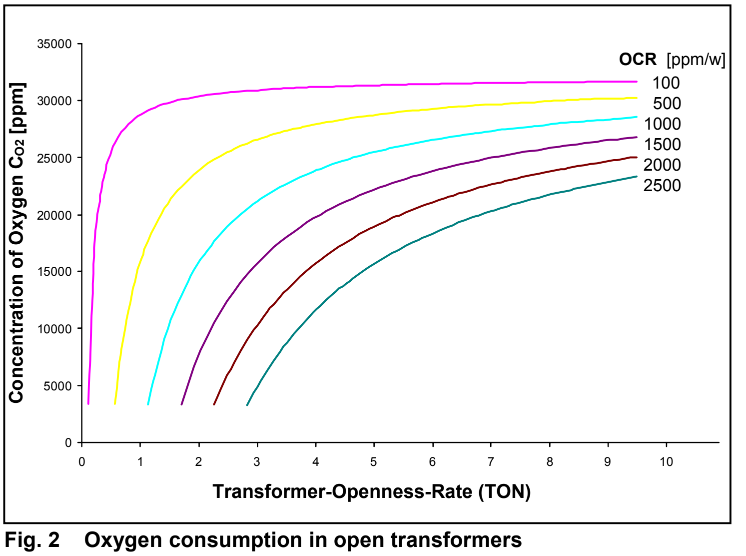

Fig. 2 Oxygen consumption in open transformers

4. Gas emission rate (GER) for fault gases of little solubility in oil

Fig 1 shows the different behaviour of the fault gases. The carbon dioxide, which is well soluble in oil, increases steadily during the monitoring time, in the same way as in a closed transformer, which would also apply to the hydrocarbons, which are well soluble in oil. However, due to the losses caused by the open type construction, the fault gases hydrogen and carbon monoxide, which dissolve only little, show stationary levels. So it is not possible to determine the GER through difference measurements according to the norm. The functional relation between fault gas concentration (c_{FG}) and gas emission rate can be inferred on basis of the transformer openness number. The curves for hydrogen and carbon monoxide (Fig. 3) result from suspect c_{FG} values and post installation hermetic sealing of determined GER values. The risk of increased GER values (> 5 ppm H_2/w or > 50 ppm CO/w) begins with c_{H2} > 40 ppm or c_{CO} > 400 ppm. In this case, the accurate determination with the known TON is recommended. Practical examples for quotients of fault gases with good oil solubility and little oil solubility (C_2H_2/H_2, CO_2/CO) show suitable diagnostic results on the basis of GER values.

Concentration quotients can be too high up to factor 10. The same has to be considered for each diagnostic scheme in which is hydrogen involved.

Concentrations of fault gases with little solubility in oil are not suitable for diagnoses; however the gas emission rates which show the presence of the fault and allow the determination of the fault type, are.

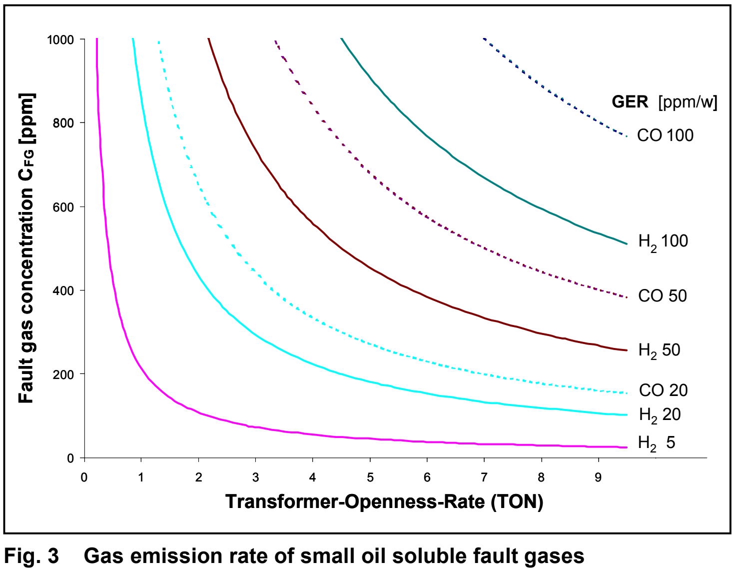

Fig. 3 Gas emission rate of small oil soluble fault gases

GATRON
GATRON GmbH | Brandteichstrasse 20 | D – 17489 Greifswald
Telefon: ++49(0)3834-51 49 30 | Telefax: ++49(0)3834-51 49 320
E-mail: mail@gatron.de | Web: www.gatron.de