Data Issues in Transformer DGA

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I. Introduction

Power transformers are designed to pass large amounts of energy through with very high efficiency, so in normal operation and in the absence of unusual stress there should be no degradation of the oil and paper insulation inside the transformer. Insulation damage or degradation resulting from an abnormal condition ("fault") is almost always detectable by the formation of characteristic gaseous byproducts in the transformer oil. The main concern of transformer dissolved-gas analysis (DGA) is to detect, quantify, and interpret the active production of fault-related gas when it occurs. There are various issues that can interfere with or complicate that. Those issues must be recognized and dealt with before a final conclusion can be reached when interpreting new DGA data.

Not much can be concluded from the analysis of a single transformer oil sample. It is impossible to be confident in the gas concentration values for an isolated or first sample until the data for another sample are available for comparison. If successive sample results are in good agreement, it is reasonable to conclude that they represent the state of the dissolved gases in the transformer fairly and that the transformer appears to be operating normally. If successive sample results do not agree, or if they don't seem to make sense, then the question is "Why not?" Various answers to that question must be considered and excluded before concluding that fault-related gas production is the best explanation.

II. Common DGA data issues

A. Gas concentrations vary greatly from sample to sample, and not all in the same direction

Exaggerated variability of gas concentrations from sample to sample may indicate that some or all of the oil samples that are being collected are unrepresentative. Improvements of sampling method and technique may be needed [1].

A different or contributing cause for large variability of gas concentrations is high measurement uncertainty due to quality control problems or lack of skill at the laboratory. Multi-laboratory round-robin tests using prepared gas-in-oil samples indicate that when there are no sampling problems a competent transformer oil lab should produce DGA results with about 10% to 15% measurement uncertainty [2], [3].

DGA results that are extremely variable from one sample to the next make it difficult to detect incipient faults or to identify accurately and judge the severity of faults that have been detected.

B. One oil sample's gas concentrations are very different from the other samples

Inconsistency in gas concentrations can point to a misidentified sample – for example, an LTC oil sample that is incorrectly labeled as belonging to the main tank, or a sample from a different transformer.

If only one or two gas concentrations for a sample are unusual, a possible explanation is some kind of data transcription error:

- N_2 and O_2 values interchanged
- CO and CO_2 values interchanged
- Duplicated, reversed, or dropped digits; for example, 88 instead of 8, 93 instead of 39, or 430 instead of 4300.

Another possible explanation of "exceptional" sample results is that it is simply a "bad sample," i.e., because of some unknown problem with sampling, handling, or lab processing, some numbers in the lab report are simply incorrect.

C. Contradictory information

If the hydrogen concentration decreases sharply while other gases remain roughly the same as before or even increase, the oil sample was probably exposed to air at some point or a gas bubble was expelled from the sample syringe. Additional evidence for air exposure would be loss of some or most carbon monoxide and a large increase in the oxygen/nitrogen ratio.

If one gas concentration other than hydrogen decreases sharply while others stay the same or increase, the change is likely to be a transcription error as discussed in II-B.

If one gas increases significantly while others do nothing or decrease, there may be stray gassing or a transcription error as discussed in II-B.

D. Hydrogen concentration is extremely low in all samples

Because of their relatively low solubility in oil, hydrogen and carbon monoxide are quickly lost to the atmosphere if they have a way to escape from the transformer or the sample container. With its low molecular weight, hydrogen escapes particularly quickly. If hydrogen and carbon monoxide levels are consistently low, and the oxygen/nitrogen ratio is consistently 0.2 or more, the transformer may be "breathing" either by design or because of a leak or a ruptured conservator diaphragm.

If the transformer is losing gas from the oil or headspace to the atmosphere, there should be simultaneous declines or decreasing trends in all or most non-atmospheric gas concentrations. Loss of gas can mask fault gas formation or cause it to be underestimated because the reported fault gas concentrations do not represent the full amount of fault gas produced in the transformer. In order for fault-related gassing to be discoverable in a breathing transformer, the gas generation rate has to exceed the loss rate.

Another possible explanation for consistently low or zero hydrogen levels, even if the oxygen/nitrogen ratio is consistently below 0.2 and gas concentrations are not continually or intermittently declining, is a sensor problem or misconfiguration of the laboratory's gas chromatograph. In that case, the reported concentrations of fault gases other than hydrogen and carbon monoxide are not necessarily inaccurate.

E. After the oil is degassed, gas concentrations start trending upwards

The large quantity of oil-saturated paper winding insulation in a transformer traps some of the gas that is dissolved in the oil, and oil replacement or degassing is completed before much of the trapped gas can diffuse out of the winding insulation into the low-gas oil. After degassing or oil replacement is complete, the slow process of equalization of the gas concentrations between the windings and the rest of the oil will produce simultaneous upward trends in all gases for a few weeks or months until the gas concentrations in the oil inside and outside the paper insulation are the same. Typically, but depending on the oil-paper mass ratio of the transformer and other factors, about 10% to 15% of the initial gas level reduction will eventually be restored by this process. Only after the fault gas levels have "rebounded" at least to that extent can further gas increases be considered to indicate active fault gas production.

F. Recurrent gas loss

If in the DGA history of a sealed or gas-blanketed transformer there are recurrent instances where non-atmospheric gas concentrations decrease simultaneously, the cause may be repeated instances where headspace gas is expelled through a pressure relief valve in connection with thermal cycling. In extreme cases that kind of gas loss can mask fault-related gas production, turning a steady upward trend into a "sawtooth" pattern. It may be possible to add together the amounts of increase between gas loss incidents to assess the rate of fault gas production, if any.

There are cases where transformer owners de-gas a transformer whenever its dissolved-gas concentrations exceed a limit. Often this is done in the mistaken belief that the gases themselves are harmful to the transformer and the degassing is solving a problem. As noted in paragraph II-E above, there is a "rebound" period following degassing during which it is nearly impossible to recognize or evaluate genuine fault gas production, so repetitive degassing can greatly interfere with recognition and assessment of fault-related gas production.

III. Final recommendations

When abnormal-looking DGA results are discovered, get a verification sample to confirm that there is a transformer problem rather than a data problem before taking drastic action. Always be cautious about approaching or sampling an energized transformer that may have something wrong with it.

Use commercially prepared gas-in-oil standards for checking the quality of lab DGA results. Also occasionally collect a transformer oil sample in several syringes at the same time and distribute them to different labs to compare results.

Data problems are not always the lab's fault. Be as careful as possible with sampling, labeling, and shipping oil samples. Keep the lab informed of all changes to equipment inventory and identification.

References

[1] T. Rhodes, "Using field moisture probes to ensure drawing a representative oil sample," in *82nd Annual International Doble Client Conference*, March 2015.

[2] M. Duval and J. Dukarm, "Improving the reliability of transformer gas-in-oil diagnosis," *IEEE Electrical Insulation Magazine*, vol. 21, no. 4, pp. 21–27, July 2005.

[3] B. N. Taylor and C. E. Kuyatt, "Guidelines for evaluating and expressing the uncertainty of NIST measurement results," US National Institute of Standards and Technology, NIST Technical Note 1297, 1994.