Current Trends in Continuous Gas Monitoring of Pad-mounted Transformers

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Increased competition and the push to reduce the cost of energy (LCOE), combined with the expiry of PPAs and production tax credits, have renewable energy asset operators seeking out new ways to reduce liabilities, especially losses in the Balance of Plant (BOP) systems and its O&M costs.

For this purpose, pad-mounted transformers are a prime operational optimization candidate. Advances in transformer condition-based monitoring (CBM) technologies and data analytics are currently disrupting industry benchmarks in medium voltage (MV) transformer health and efficiency. CBM enables operators to track transformer performance in real-time to avoid costly catastrophic failures and move towards just-in-time preventative maintenance and intelligent run-to-failure.

Importance of Assessing Transformer Health

As the essential interface between individual assets and the BOP collection system, medium voltage transformers play a critical role in renewable energy generation systems. Transformer failure can lead to cascading failures further up (i.e., grid) and down the BOP (i.e., individual fleet assets). Non-isolated transformers and/or cable damage can incapacitate the entire feeder section of a facility, not to mention cause increased worker health and safety risk, strain other BOP components, increase insurance premiums, and expose the operator to the risk of NERC incompliances.

Transformer health is closely linked to hydrogen concentrations: variations of a few tens of ppm can have a dramatic impact on transformer operation and performance [1]. Traditionally, operators have relied on sampling of transformer oil every 6–12 months to identify abnormal concentrations of gases such as hydrogen and acetylene in the oil. This process requires multi-asset outages to extract oil samples. Gases are analyzed off-site and compared to previous measurements to assess transformer health.

The effectiveness of the oil measurement can be assessed using two criteria: how reproducible is the measurement and how accurately does it represent the true, underlying condition of the transformer?

The main factor determining the reliability of traditional oil sampling analysis is the poor repeatability of manual sampling [2]. Because the transformer is taken out of its natural load profile when the oil sample is taken, the dissolved gas levels do not reflect the transformer's actual operational health: the temperature changes and there is no guarantee that the gas distribution does not change when the transformer is down; and, levels of dissolved gases could also be affected. Further, bad sampling techniques and inappropriate storage have been shown to introduce contaminants and cause a loss of gas from the oil [3].

Because transformer health is acutely sensitive to hydrogen concentrations in the oil, uncertainty of measurement plays a vital role in determining the diagnostic value of the transformer oil sampled. Research has shown spreads of several hundreds of a percent between samples from the same asset tested at different laboratories using different techniques [1]. These errors are significant and entail that traditional manual oil sampling analysis is not sufficiently reliable, offering only limited diagnostic value to operators, in particular when one considers the importance of MV transformers within the BOP.

Accurately Monitoring Transformer Health

Periodic manual oil sampling does provide a snapshot of transformer health at a given moment in time, but the underlying health of the transformer is unknown between sampling intervals. This exposes operators to increased liabilities including preventable transformer failures and the health and safety and environmental hazards of transformer ruptures.

Current preventative maintenance standards require operators to accurately track fluctuations in transformer performance over time to diagnose rapidly developing faults and prevent catastrophic transformer failure. This is best done by implementing an online CBM.

Consider the three transformers shown in Figure 1. The top panels show the actual hydrogen concentrations in the transformer oil for three cases: transformer 1 has a constant hydrogen level over a two-year period; transformer 2 shows a significant spike in hydrogen levels over a six-month period; transformer 3 has a moderate increase in hydrogen levels followed by an extend period of constancy. The hydrogen spike experienced by transformer 2 could indicate failing transformer health and eventual asset failure, while transforms 1 and 3 present normal, healthy operation conditions.

Periodic manual sampling data (plotted in the middle panels of Figure 1) does not reveal the significant differences in hydrogen concentration trends found in the three transformers. The concerning hydrogen spike in transformer 2 is altogether missed by periodic sampling. The limitations of periodic sampling are compounded by the fact that demanding operation schedules during high production season make it very unlikely that asset owners would schedule a sampling outage at this time, causing a higher risk of failure just when operation performance and reliability are most critical.

To have an accurate and reliable understanding of the underlying transformer health, operations managers need to monitor hydrogen concentrations on an ongoing basis. Only continuous gas monitoring offers operations managers the ability to detect failures in their early stages, as shown in the bottom panels of Figure 1.

Continuous gas monitoring enables the operator to observe the increased hydrogen concentration in transformer 3 in the early samples. This helps the operator make an informed decision to keep the transformer in operation because they can see the failure is not progressing rapidly, which indicates that the asset could have substantial service life remaining. Using continuous monitoring, the asset can be safely kept in operation under stricter monitoring requirements, without having to stop production to take more samples.

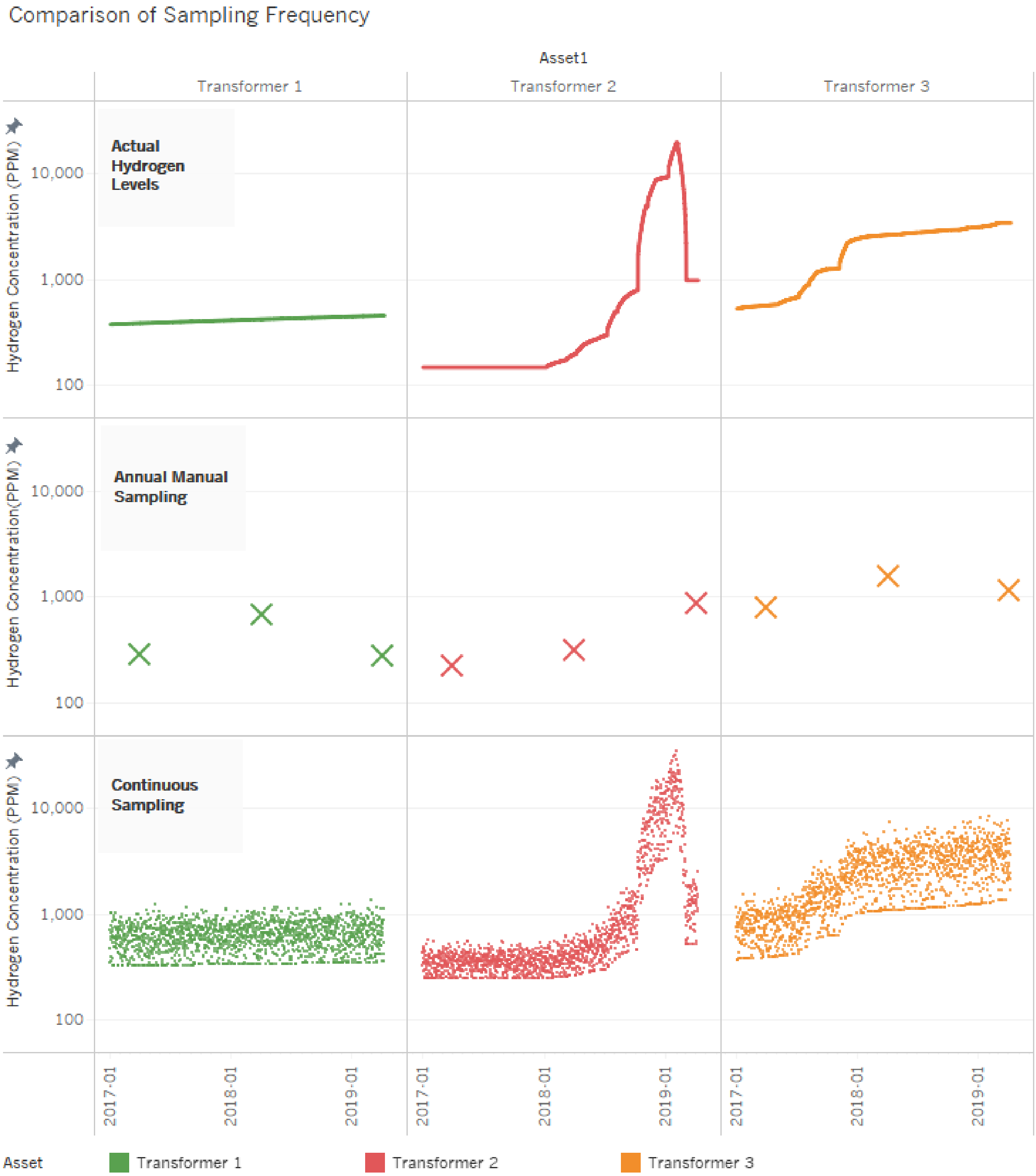

Figure 1 Comparison of sampling frequency. Top: Actual hydrogen levels in transformers over time. Middle: Hydrogen levels measured using manual periodic sampling every 12 months. Bottom: Hydrogen levels measured using continuous gas monitoring.

Combining Accuracy and Reliability

Optimal system operation requires measured transformer health to accurately and reliability reflect underlying asset health, at a high enough sample rate to be diagnostically effective, as shown in Figure 2a. Periodic manual sampling precludes this not only because of the limited quantity of data, but also because of the high degree of uncertainty associated with the data due to changes in operation conditions and potential sample contamination. Figure 2b highlights how sampling inaccuracy leads to deviations between the measured asset health and the underlying asset health.

Only continuous gas monitoring provides operators with increased measurement reliability at a diagnostically effective sample rate with a more accurate representation of underlying transformer health, as shown in Figure 2c. This enables operation managers to move closer to the ideal condition monitoring scenario, in which the measured transformer health provides an accurate and reliable indication of the underlying transformer health.

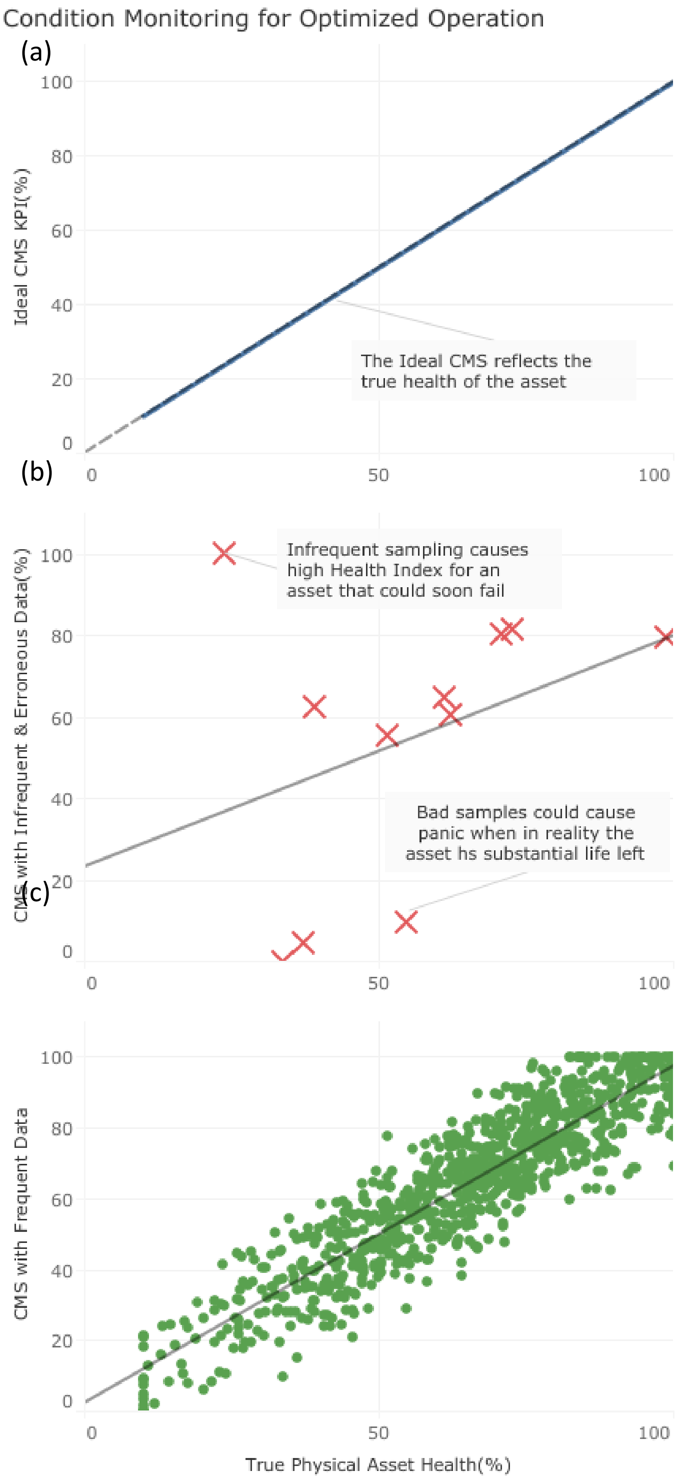

Figure 2 Condition monitoring scenarios. (a) Ideal condition monitoring, in which measured data correspond exactly to true asset health. (b) The presence of a few bad samples means that periodic manual sampling does not provide a reliable or accurate representation of underlying asset health. (c) Continuous monitoring leads to improved correspondence between measured and actual asset health, as well as increased propensity towards improved asset health.

Continuous Transformer Monitoring to Increase Operational Efficiency

A decade ago, periodic manual sample would have provided adequate diagnostic information for medium voltage transformers. However, even then, the price of antecedent dissolved gas analyzers limited their application to larger grid-side transformers, and their installation, operation, and integration into existing the diagnostic infrastructure was cumbersome and expensive.

By contrast, recent advances in gas concentration measurement techniques and wireless communication technology have facilitated the integration of continuous dissolved gas measurement into existing diagnostic systems easily and cost-effectively.

Qualitrol's DGA-LT1 is quickly and non-invasively installed on the drain valve of existing MV transformers, requiring no modification to the OEM design, and without the need to install power or communication cables because it is solar-powered. The DGA-LT1 does an exceptional job of combining the economic value of industrial production and quality with the diagnostic value of the latest CBM technology which has come to be expected at every level of current wind operations and which is slowly finding its way into solar operational standards as well.

Whether an operator chooses to pursue a path of preventive maintenance or calculated run-to-failure, continuous transformer monitoring using the DGA-LT1 provides operators with access to reliable and robust data, while eliminating the uncertainty causing speculative changeouts, as well as reducing risks to the environment and maintenance personnel caused by switching and extracting test samples or working near the units.

Continuous monitoring leads to mass improvements in transformer health and operation performance, and these benefits ripple and multiply up and down the BOP infrastructure chain. Operators now have the ability to react immediately to contain rapidly developing catastrophic sequences, while simultaneously reducing risk exposure to technicians and the environment. This entails trimmer operations by reducing lost production time created by transformer failures and extending the service life of transformers, while also reducing secondary stress on proximate BOP infrastructure. Trimmer and safer operations result in more productive relationships with all stakeholders, from NERC and the underwriters to land-owners and technicians. For renewable energy system operators, that's the sum ROI of implementing CBM in their pad-mounted transformers.

For more information, you can check out the product page here.

References:

[1] M. Duval, “Dissolved gas analysis: It can save your transformer,” *IEEE Electr. Insul. Mag.*, vol. 5, no. 6, pp. 22–27, Nov. 1989.

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