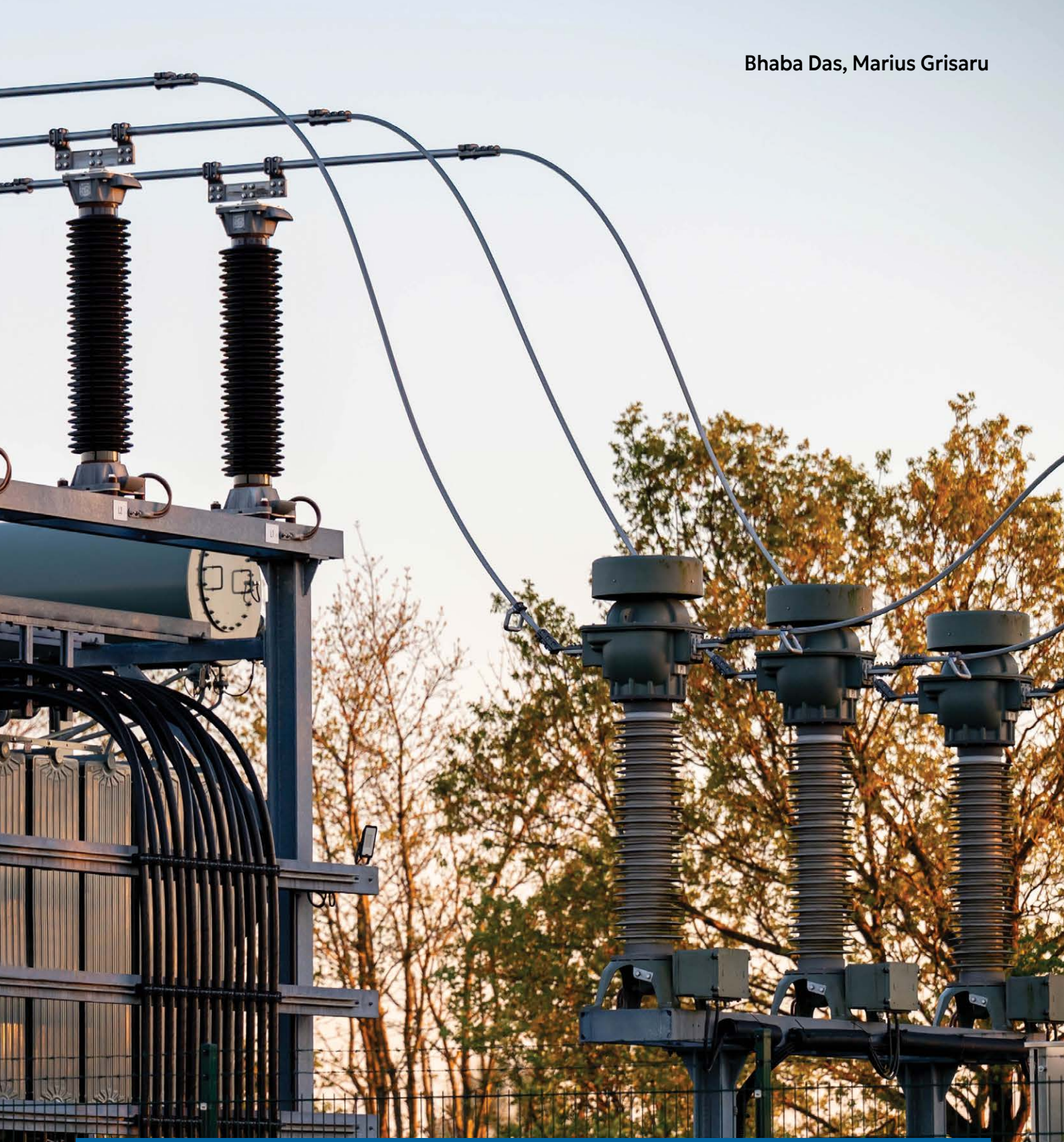
Beyond Fixed Limits

Baseline-driven, trend-focused Online DGA alarm strategy

Part II



Bhaba Das, Marius Grisaru



ABSTRACT

Across the various condition monitoring options available for transformer health, Online Dissolved Gas Analysis (ODGA) has become the go-to early warning system. Yet too often, alarm logic still relies on static ppm thresholds that ignore a unit's context, leading to nuisance alarms and operator fatigue. This article presents a practical, standards-aligned methodology moving from fixed limits to transformer-specific baselines, population statistics, and noise-robust Rate-Of-Change (ROC) and explains how to cut false positives without compromising sensitivity. It draws on advice from IEC 60599, IEEE C57.104-2019, CIGRE TB 403 & TB 771 & TB 783, and recent industry experiences.

KEYWORDS:

DGA, online DGA, transformer condition monitoring, monitoring systems

Short-window ROC is useful for situational awareness but unsuitable for alarms

Continued from Part 1, published in the May 2026 Special edition of Transformer Magazine

1. Introduction and Recap

This article is a continuation of Part I, published in the May 2026 Special Edition of Transformer Magazine. Part I established the conceptual and statistical foundation for a baseline-driven, trend-focused Online DGA alarm strategy: it introduced transformer-specific baselines, the role of medians and percentiles in describing normal gas behaviour, a layered escalation framework combining unit-specific and population-based thresholds, and generic two-level provisional screening values for absolute gas concentrations (Tables 1-6 in Part I).

Part II addresses the remaining elements of that framework, focusing on the Rate-of-Change (ROC) dimension: how it should be calculated, over what time window, and how it should be combined with absolute exceedance criteria to yield alarms that are both sensitive and selective. Practical implementation considerations - including the rolling versus fixed-window debate and the special case of monitoring a transformer under a managed degradation or nursing protocol - are also addressed. Table numbering continues from Part I; Tables 1-6 were presented in the previous issue.

1.1 Rate-of-Change (ROC): The critical dimension

As noted in Part I, the population-derived ROC values in this section originate from mineral-oil transformer databases (IEEE C57.104-2019 and CIGRE TB 771). For natural- or synthetic-ester-filled transformers, baseline H_2, CO, and CO_2 generation may differ markedly from mineral oil because of higher stray gassing, ester-linkage pyrolysis, different solubility behavior, and different aging chemistry. The numerical thresholds in Tables 7, 8, and 10 should therefore be regarded as starting points for mineral-oil units only; ester-filled fleets require unit-specific baseline characterization before any of these values are deployed as alarm settings.

While absolute gas concentrations provide a snapshot of transformer condition, they offer limited insight into whether a fault is stable, progressing, or newly emerging. In ODGA monitors, ROC is therefore the most powerful discriminator between benign long-standing conditions and active fault development.

Both IEC 60599 and IEEE C57.104-2019 explicitly emphasise trend evaluation over single-point measurements. IEEE C57.104-2019 derives gas generation rates using linear regression across multiple laboratory samples spanning months or years, and reports 95th percentile ROC values that represent the upper bound of statistically normal population behaviour. Similarly, CIGRE Technical Brochure 771 provides typical, intermediate, and pre-failure gassing rates based on real transformer case histories.

It is important to note that these published ROC values are not short-term derivatives. They are long-window indicators designed to reflect the kinetics of physical degradation processes rather than measurement noise or operational transients. Translating this intent into ODGA monitoring requires selecting ROC windows that preserve the same physical meaning.

ODGA systems often calculate 1-day or 7-day ROC values because they are computationally simple and visually responsive. While useful for situational awareness, such short-window ROC is dominated by non-fault influences, including:

- temperature-dependent gas solubility,
- oil circulation and mixing delays,
- transient loading events,
- sensor noise and repeatability limits.

As a result, short-window ROC frequently exaggerates normal variability and produces unstable slopes that have no direct relationship to fault energy or severity. Alarm thresholds based on 1-day or 7-day ROC therefore tend to oscillate, generating false positives and undermining operator confidence. This behaviour is fundamentally inconsistent with IEC, IEEE, and CIGRE methodologies, which are based on longer trend evaluation.

A 30-day (or longer) ROC window provides a practical compromise between sensitivity and stability. At this timescale:

- transient thermal and operational effects are largely averaged out,
- sensor noise is significantly attenuated,
- the resulting slope reflects sustained gas generation rather than momentary fluctuations.

To summarize, short-window ROC is useful for situational awareness but unsuitable for alarms.

- 1-day ROC, primary purpose is for change detection, but not suitable for alarms.

Table 7. Typical ROC values (30-day window)

Gas	IEEE 95th ROC (ppm/30 days)	CIGRE Typical ROC (ppm/30 days)	Inference
H_2	~2	~1.8	Similar
CH_4	~1	~1.3	Similar
C_2H_6	~1	~1.2	Similar
C_2H_4	~1	~1.0	Similar
C_2H_2	Any increase	Any increase	Similar
CO	~8	~16	CIGRE is 2x
CO_2	~100	~135	Similar

- 7-day ROC, primary purpose is for engineering review, but not suitable for alarms.
- ≥ 30-day ROC, primary purpose is for condition classification, suitable for alarms.

This aligns closely with the way IEEE and CIGRE gas generation rates were originally derived and ensures that online ROC thresholds remain physically interpretable.

The primacy of trend information over absolute concentration levels has been discussed in detail for hydrogen interpretation, which is the most measured and monitored gas in transformer condition monitoring [6].

Table 7 (typical ROC values) illustrates that IEEE 95th percentile and CIGRE "typical" gassing rates are remarkably consistent when converted to a 30-day basis, reinforcing the validity of this window for alarm setting.

Table 8 further shows how ROC accelerates dramatically as faults evolve toward failure, often by one to two orders of magnitude [4].

To establish a recommended setting for ODGA monitors, Table 9 gives a conceptual band.

The original concept is to trigger an alarm before the CIGRE pre-failure (PF) value is reached, because PF values are derived from transformers that failed or were removed from service, are often observed very close to failure, and may be too late as a first point for online monitoring.

Using 1/2 PF as an alarm reference is therefore a conservative engineering choice that is compatible with the intent of IEC 60599 and IEEE C57.104-2019, because it acts before pre-failure rates are reached and remains above normal population ROC levels for most gases. It should not be presented as a formal standard requirement and must be validated against transformer-specific behavior, monitor uncertainty, and fleet experience.

Important caveat ; C_2H_2 false readings in ODGA: Multi-gas online DGA devices may occasionally produce spurious

A small increase in C_2H_2 is inherently more severe than an equivalent increase in CO

Table 8. CIGRE ROC values observed near failure [4]

Gas	Intermediate 1 (ppm/30 days)	Intermediate 2 (ppm/30 days)	Pre-failure (PF) (ppm/30 days)
H_2	6	11	90
CH_4	5	12	150
C_2H_4	4	11	150
C_2H_6	7	17	330
C_2H_2	0	1	15
CO	60	130	1420
CO_2	520	1140	12500

Table 9. Conceptual band for ROC based alarms

Conceptual band	Standard reference	ODGA Action
Normal	CIGRE Typical / IEEE <95%	No alarm
Developing fault	CIGRE Intermediate	Caution
Active fault	≥ ½ × Pre-failure (PF)	Alarm

Table 10. Generic 2-level ROC limits for ODGA monitors (non-nursing transformers)

Gas	ROC (30 days) Caution	ROC (30 days) Alarm (1/2 PF)	Severity
H_2	6	45	Medium
CH_4	5	75	Medium
C_2H_4	4	75	High
C_2H_6	7	165	Low
C_2H_2	1	8	Very High
CO	60	710	Low
CO_2	520	6250	Low

Note for C_2H_2: The numerical value of 8 ppm/30 days represents an urgent or severe escalation reference, not the first alarm point. Any reproducible increase in C_2H_2 above the unit-specific noise floor or the confirmed limit of quantification should trigger expert review and confirmatory laboratory DGA.

End users can end up suppressing alarms, raising thresholds or distrusting the ODGA monitor altogether, ironically defeating its purpose

C_2H_2 readings due to gas-specific interferences, detection-limit behaviour or sensor-model limitations, particularly in some photo-acoustic and infrared-based devices. A C_2H_2 indication should therefore not trigger immediate field intervention based on the online reading alone. It should trigger urgent expert review and confirmatory laboratory DGA, especially when H_2, C_2H_4 and CH_4 are not proportionally elevated. Users should establish the C_2H_2 detection floor and cross-interference characteristics for the specific ODGA device as part of the TB 783 performance verification process [5].

The operational interpretation of short-term changes should also consider gas identity. A small increase in C_2H_2 is inherently more severe than an equivalent increase in CO. In general, C_2H_2 is treated as the most critical, CO as comparatively less severe, with H_2 and CH_4 at similar intermediate severity.

Table 10 ranks each gas individually. When applying these values to alarm logic, the diagnostic value of gas pairs should be retained. Simultaneous H_2 and C_2H_2 rate-of-change above caution levels, even below the 1/2 PF alarm threshold for either gas alone, is a stronger indicator of active fault development than either gas considered in isolation. H_2 is often an early gas in partial-discharge and thermal-electrical faults, while C_2H_2 has unique discriminatory value for arcing (D1/D2). This combined-indicator philosophy is developed further in [7].

For units with documented stray gassing (CIGRE TB 771 category S), the H2 caution and alarm thresholds in Table 10 should be elevated above the unit-specific stray-gas baseline rate, not the population value. Stray-gas chemistry alone can drive 30-day H_2 ROC fluctuations comparable to the caution threshold. In such cases, C_2H_2 ROC remains the most reliable single-gas high-severity trigger, subject to the laboratory confirmation caveat above.

CO and CO_2 trends should be treated primarily as oil-paper ageing, oxidation, breathing and maintenance-context indicators, not as stand-alone severe-fault alarms. Their interpretation should be cross-checked against O_2 & N_2 behavior, inhibitor status, IFT, acidity, water, furanic compounds, methanol/ethanol (where available), and recent oil-treatment history.

1.2 ROC: Rolling or fixed window calculation for ODGA?

In practical implementations, ROC is derived over a moving time window in ODGA monitors, using filtered or smoothed gas values to reduce the influence of measurement noise, temperature effects, oil circulation dynamics, and sensor repeatability. Typically, the moving time window ~ 1, 7, 14, or 30 days which is vendor dependent. As raw online gas data is noisy, vendors apply one or more of – moving average, exponential smoothing, median filters, etc.

Rolling window calculations continuously update the ROC as new data becomes available, which can amplify transient effects and cause the same short-duration event to repeatedly enter and exit the calculation window. While rolling windows may offer faster fault detection in theory, in practice they often lead to unstable alarm behaviour unless aggressive filtering and confirmation logic are applied. For this reason, rolling ROC calculations are better suited to operator visualization, whereas fixed window ROC calculations are better aligned with long-term trending, fleet comparison, and alarm setting practices recommended in IEEE and CIGRE guidance.

Rolling ROC calculations are embedded in ODGA monitor firmware for the following practical reasons:

- ODGA monitors are built as real-time instruments, not statistical engines:

Table 11. Comparison for rolling and fixed window ROC calculations

Feature	Rolling ROC	Fixed-window ROC
Ease of implementation	Very easy, incremental calculation	Harder, needs reference storage and interpolation
Sensitivity to short-term spikes	High: reacts to transient noise or short-term load fluctuations	Low: smooths out transient spikes
Trend clarity (daily/long-term)	Medium: may be noisy due to load swings	High: captures overall daily trend reliably
Alarm standardization	Hard: depends on window size and sampling rate	Easy: aligns with standard 24-hour thresholds
Memory requirement	Low: only last N samples needed	Medium/High: reference value and possibly full day's data needed
Diurnal operating effects	Rolling ROC may overreact to normal daily load swings, giving false indications!	Fixed-window ROC reduces impact of daily load/temperature cycles; gives more meaningful daily trend.

no fixed reference is needed, the system works with streaming data, variable sampling intervals are tolerated, and the calculation is memory efficient.

- Operations personnel often want to know what changed since yesterday, right now. This is intuitive and actionable, so vendors optimize for operational responsiveness as well as physics.
- Rolling ROC aligns naturally with continuous sampling and fits into real-time trending dashboards.
- Guides and standards do not explicitly forbid rolling windows, so rolling ROC persists by legacy inertia.
- Rolling ROC is conservative for fast, violent faults; vendors often justify it by saying that they want the fastest possible detection.
- It is computationally simple, operationally intuitive, legacy-compatible, and aligned with real-time monitoring paradigms.
- The rolling-window philosophy implicitly accepts that false positives may

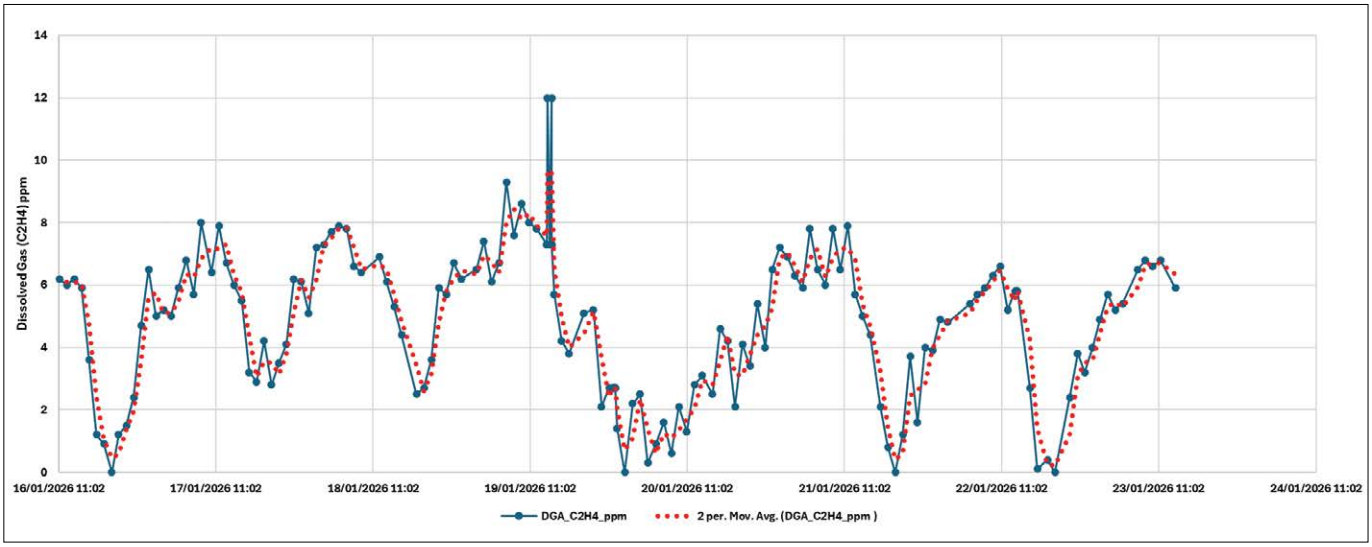


Figure 1. Online Dissolved Gas data for a period of 7 days

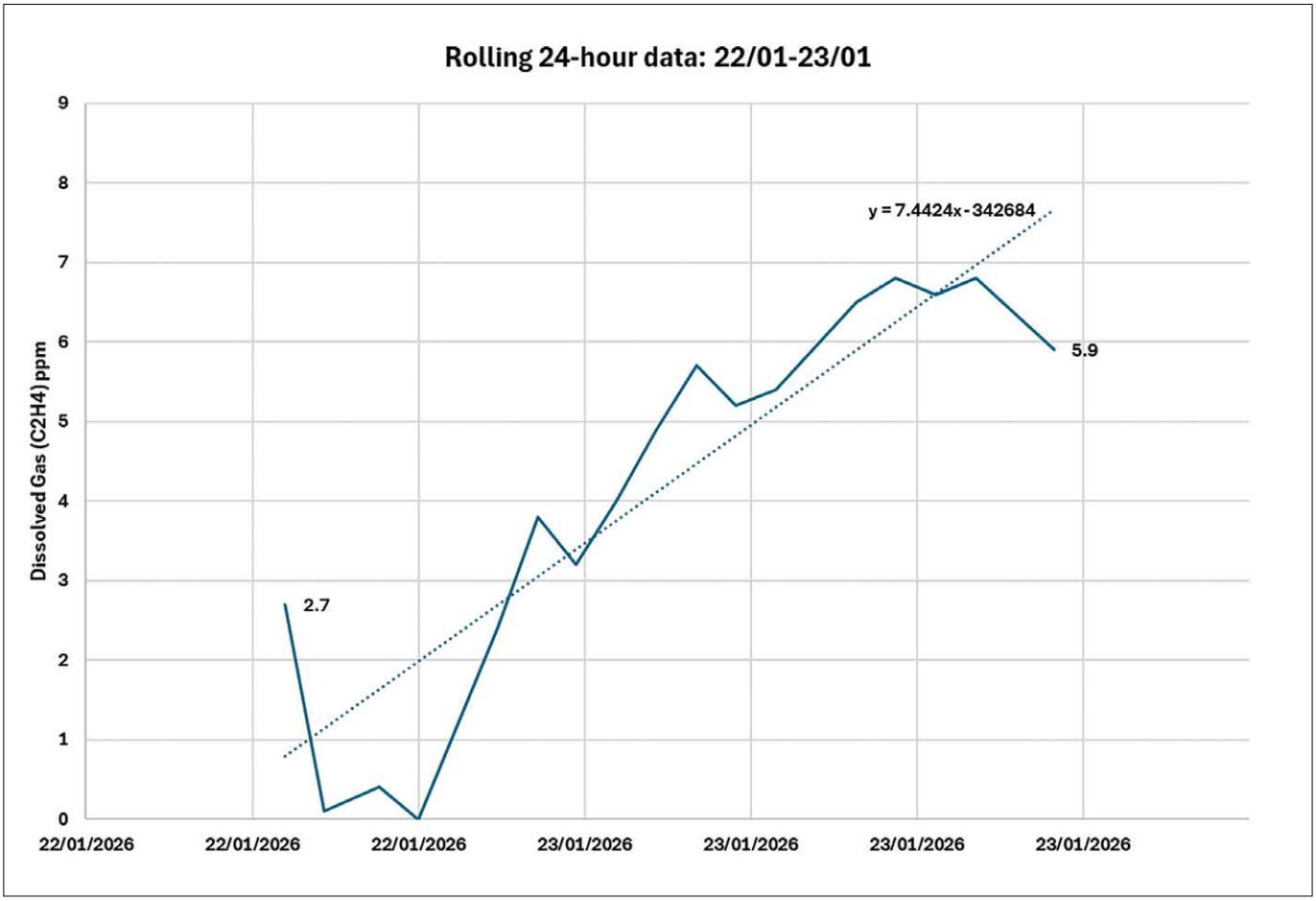


Figure 2. Online Dissolved Gas data: 24-hour rolling window

In practice, distinguishing spikes from genuine changes requires determining the effective noise level of each monitor individually, rather than relying only on generic manufacturer specifications

be tolerated in exchange for rapid detection.

However, end users then end up suppressing alarms, raising thresholds or distrusting the ODGA monitor altogether, ironically defeating its purpose.

For diagnostic interpretation and alarm strategy development, fixed daily 24-hour ROC calculation (which extends to 7-day, 14-day or 30-day ROC) can therefore provide a complementary perspective by integrating gas behaviour over a complete transformer cycle and enabling more consistent day-to-day comparison. A comparative table is presented in Table 11.

Even when calculating longer-window ROC values such as 7 days or 30 days, using a fixed 24-hour boundary for each day (e.g., midnight-to-midnight local site time or standardized UTC) produces significantly cleaner, more stable trends than using rolling 24-hour windows. A rolling window "slides" continuously with each new DGA reading, which means the start and end points of the 24-hour segment shift with every measurement. This creates window-jitter artifacts, where the ROC value fluctuates not because of a real change in gassing behaviour, but because the comparison interval is drifting through different portions of the daily thermal and load cycle. Fixed-day anchoring eliminates this jitter by ensuring that each daily increment represents the same intra-day operating conditions, aligning with best practices in trend evaluation emphasized in IEC 60599, which stresses the importance of evaluating gas behaviour across consistent time intervals, and in IEEE c57.104-2019, whose ROC guidance is based on statistically stable multi-sample regressions over defined monthly spans rather than free-running short windows.

Figure 2 shows the window behaviour when the 24-hour rolling-window ROC is applied from the last point of the dataset. From Figure 2, it can be inferred that ROC is increasing on average by approximately +3 ppm/day.

Similar trends can be observed for the remaining 24-hour cycles of the entire dataset. If converted mathematically, 1 ppm/30 days is equivalent to 0.033 ppm/day. A rolling 24-hour ROC of approximately 3 ppm/day is therefore far above the IEEE-equivalent monthly rate and would repeatedly trigger alarms if the monthly guidance were applied directly to a daily rolling derivative.

A practical example from online monitoring data is shown in Figure 3, which serves as a simplified case study illustrating how rolling ROC can generate repeated false alarms despite stable underlying gassing. Even if we set 1 ppm/day, 2 ppm/day or 3 ppm/day, the rolling 24-hour window will give false alarms multiple times!

- IEEE C57.104-2019 does not use hourly or daily ROC for alarms. ODGA monitors can create such alarms only

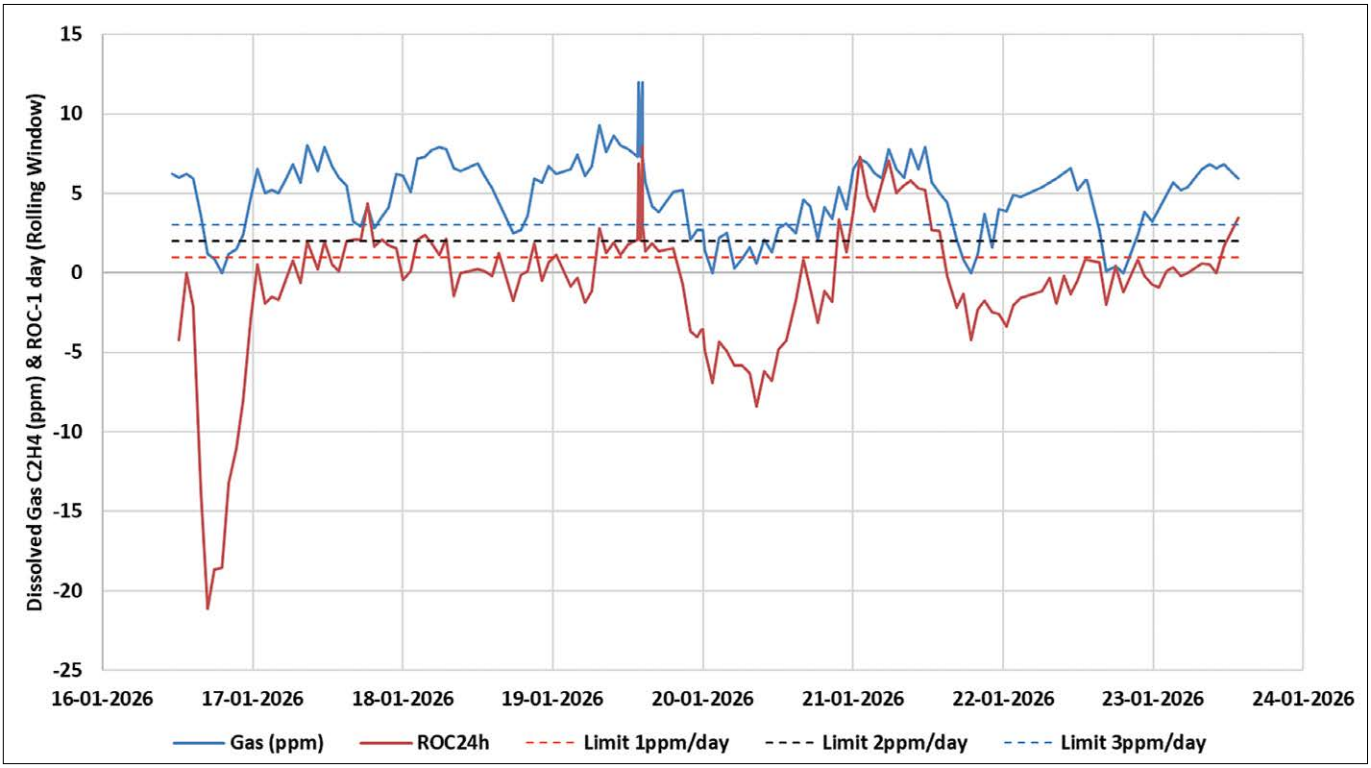


Figure 3. Online Dissolved Gas data: 24-hour rolling window and false alarms!

By smoothing normal daily variability, fixed-window ROC reduces the risk of false alarms that can arise when short-term thermal or load-driven gas fluctuations are misinterpreted as fault activity

if values intended for long-window interpretation are transferred randomly or without conversion.

In contrast, the fixed midnight to midnight 1-day ROC for all the complete days within the dataset is shown in Figure 4.

It can be inferred that fixed-window ROC:

- reflects the overall daily increase or decrease rather than intra-day oscillations,
- is closer to what an operator would interpret as the true daily rate,
- largely averages out the normal diurnal temperature and load variations that modulate gas solubility and generation,
- allows operators to compare ROC against predefined daily screening thresholds without worrying about sampling frequency or irregular intervals.

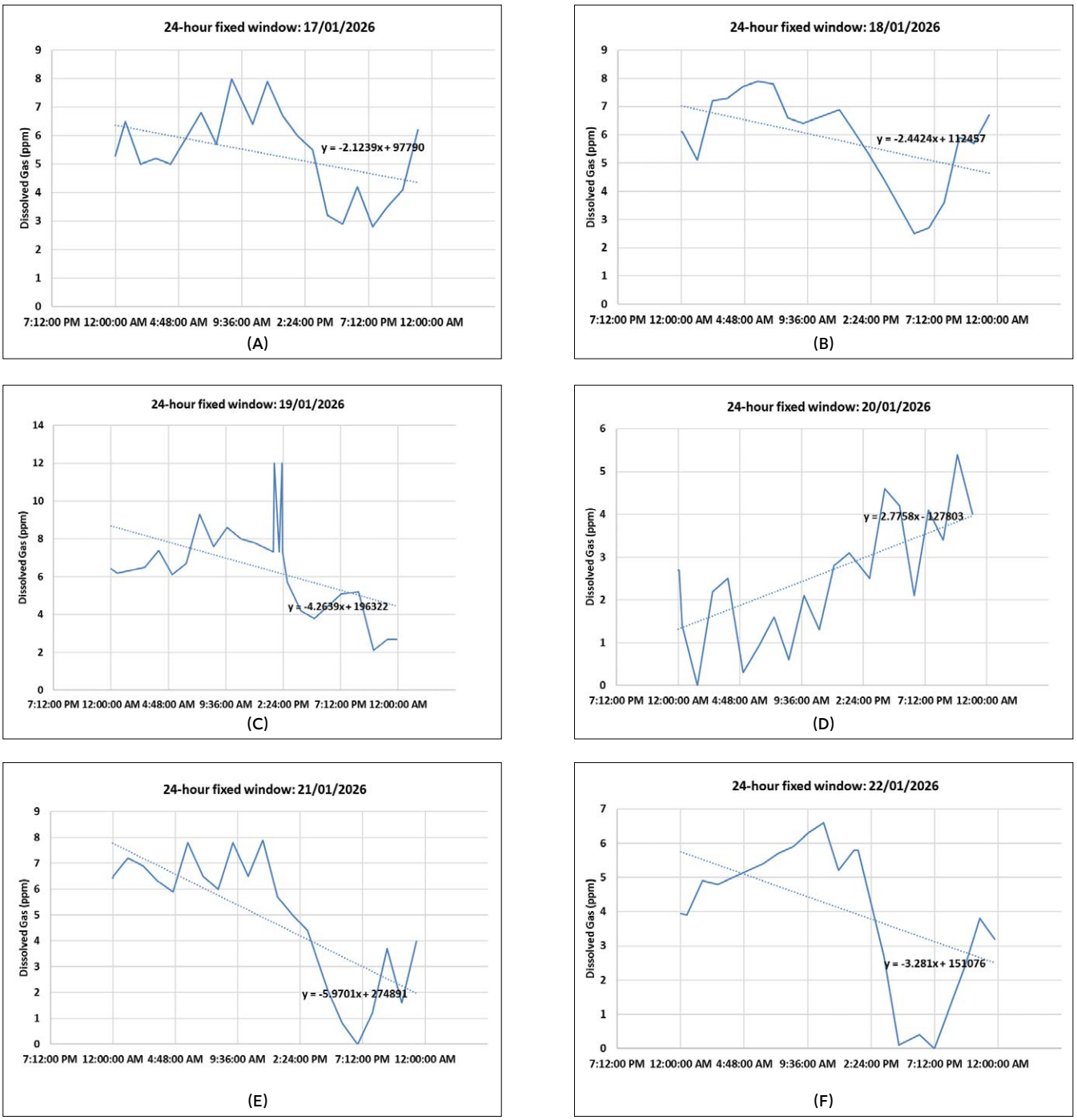


Figure 4 (A)-(F). Online Dissolved Gas data: 24-hour fixed window

Duval triangles and pentagons should always be applied whenever abnormal gas behaviour is suspected

- Fixed-window ROC, comparing midnight-to-midnight or another defined 24-hour baseline, accounts for the daily cycle and focuses on sustained abnormal increases. As shown in Figure 5, it produces only one short-term screening indication across the dataset, rather than repeated rolling-window alarm events. Final alarm classification should still rely on persistence, monitor uncertainty, gas identity and preferably 7-day or 30-day ROC confirmation.

Extending from 24-hour to 7-day or 30-day ROC should be based on gas concentration values, not on subtracting daily ROC values. The preferred method is to calculate a slope over the selected window using quality-screened daily median values, daily fixed-time values or robust linear regression of gas concentration versus time. A simpler endpoint method may also be used where data continuity is good: ROC = [C(t) - C(t - n days)] x 30/n, expressed in ppm/30 days. The 24-hour increment remains useful for screening and operator awareness, but long-window ROC is more appropriate for alarm classification.

In practice, distinguishing spikes from genuine changes requires determining the effective noise level of each monitor individually, rather than relying only on generic manufacturer specifications. Even devices of the same model can exhibit different noise behavior, and noise is further influenced by installation location, oil flow regime and loading. A unit-specific noise characterization is therefore a prerequisite for defining meaningful minimum change and ROC thresholds.

1.2.1 Why is a fixed-window ROC harder to implement in an ODGA monitor

There are several reasons why fixed-window ROC may be difficult to implement directly at the ODGA monitor device level:

1. Requires a historical reference value: the monitor must store or retrieve the midnight or other fixed-time value. If the monitor restarts, loses power or misses a sample, the reference value may be missing and the ROC cannot be computed correctly.
2. Interpolation may be needed: online monitors may sample every few hours. If the exact reference time was not sampled, interpolation between two measurements is required to estimate the reference.
3. More memory and database access are required: computation needs access to the previous day data or at least the reference point. Rolling ROC only needs the last N samples, so it is simpler for embedded devices.

While fixed 24-hour ROC provides a more stable indicator by averaging out diurnal load and temperature effects, it is computationally and architecturally better suited to other analytics platforms than to the ODGA device itself. Fixed ROC relies on consistent time references, reliable historical data retention, and sometimes interpolation to reconstruct exact day-boundary values: tasks that align naturally with SCADA, fleet monitoring, or cloud-based asset management systems. Importantly,

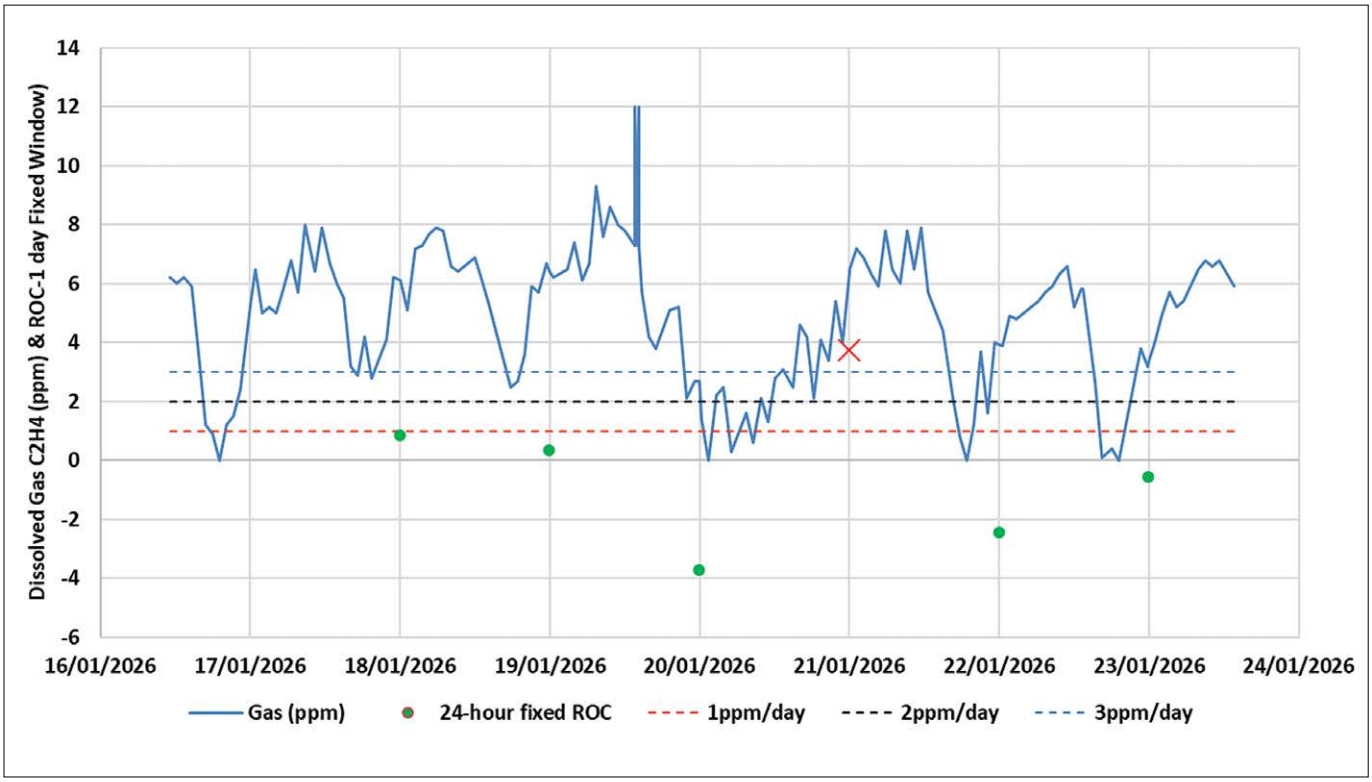


Figure 5. Online Dissolved Gas data: 24-hour fixed ROC values

by smoothing normal daily variability, fixed-window ROC also reduces the risk of false alarms that can arise when short-term thermal or load-driven gas fluctuations are misinterpreted as fault activity.

By contrast, ODGA devices are optimized for continuous measurement and lightweight, real-time calculations such as rolling ROC and threshold alarms. A layered approach is therefore emerging as best practice: the monitor focuses on high-quality data acquisition and rapid local detection, while fixed-window ROC and fleet-level interpretation are performed centrally where time synchronization, data continuity, and comparative analytics can be assured. This division of roles improves consistency, reduces device complexity, and ultimately leads to more reliable condition assessment across a transformer fleet.

2. Practical alarm philosophy for Online DGA

An effective online DGA alarm strategy combines:

- Transformer-specific baseline percentiles.
- Population reference limits (IEC/IEEE / CIGRE).
- Sustained ROC criteria.
- Confirmatory Offline DGA sample.

Rather than asking "Has a limit been exceeded?", the better question is: "Is gas behaviour changing in a way that is statistically and physically abnormal?" This approach significantly reduces nuisance alarms while preserving sensitivity to genuine fault evolution.

CO is a primary source of fleet-level false positives when used as a fault alarm trigger, because it predominantly reflects oil oxidation chemistry, breathing, insulation ageing or maintenance context rather than active fault gas generation. CO and CO2 should therefore support condition assessment, not dominate the alarm hierarchy.

Duval Triangles and Duval Pentagons may be applied as diagnostic classification tools after abnormal gas behaviour has been confirmed. They should not be used as automatic early-warning tools on baseline-level or noise-level gas data. The relevant Duval method should be selected according to equipment type, insulating liquid, gas pattern, gas concentrations above reliable detection limits and the diagnostic question being asked. The final diagnosis must then be made in context, considering transformer importance, design, loading, age, recent maintenance and other condition information [7].

Field experience and CIGRE TB 783 show that ODGA accuracy typically lies within approximately +/-10-30% under real operating conditions; alarm limits must therefore incorporate uncertainty margins [5].

CIGRE TB 409 should also be referenced for in-service calibration and accuracy verification of online gas monitors. Section 7.2 describes the practical field procedure: record the monitor reading, then immediately or rapidly take a representative oil sample from the monitor sampling point; for portable monitors, use paired samples; send the samples to the DGA laboratory; and analyse the monitor-related oil sample together with a gas-in-oil standard using the same analytical equipment. This procedure links the ODGA reading to laboratory bias, sampling repeatability and the gas-in-oil standard, and should be used before adjusting alarm margins or concluding that the online device is out of calibration [8].

A robust workflow aligns laboratory results and ODGA data through timestamp synchronization, normalization and overlay on ROC charts. ODGA monitors excel at detecting evolving conditions; offline DGA validates alarms before maintenance action. The typical immediate response to a suspicious online indication is to perform a confirmatory DGA using a portable or laboratory method. This step is a controlled diagnostic action rather than a protection alarm or automatic trip, and it helps to validate ODGA indications before major operational decisions are taken.

Confirmatory DGA should use a method validated against IEC 60567 or an equivalent recognized laboratory procedure, with documented sampling practice and inter-laboratory comparability. Apparent discrepancies between ODGA and laboratory results may reflect sampling, extraction or calibration artefacts as much as genuine ODGA error; the comparison must therefore be interpreted by a DGA specialist.

For this reason, the online-device calibration check should not be based on a simple one-to-one comparison with an uncorrected laboratory result. It should follow the CIGRE TB 409 Section 7.2 approach, in which the laboratory bias is checked with a gas-in-oil standard and duplicate samples are used to quantify sampling/laboratory repeatability [8].

Any immediate change in gas concentration that exceeds defined thresholds should be brought to a DGA specialist for review. At this stage the assessment should consider the full gas pattern, including linked indicators such as H_2 and C_2H_2. In future, AI-based advisors may assist in pattern recognition, but expert review remains essential for deciding whether an increase is operationally significant.

2.1 Special case: monitoring a transformer under a nursing protocol

When an ODGA monitor is used to nurse a transformer - that is, to consciously operate it in a controlled degraded or life-extension mode - standard alarm philosophy, which assumes a healthy baseline, will generate permanent alarms. The elevated gas concentrations present are, by definition, above normal screening limits. Applying standard absolute-concentration alarms in this context produces a persistent all-red dashboard that provides no actionable information and causes operators to distrust or disable the monitoring system.

Nursing mode requires a different alarm philosophy built around the following principles:

1. Redefine the baseline. Establish a new reference level using the current stabilised, non-accelerating elevated gas concentrations as the operational baseline. The transformer-specific 90th percentile should be recalculated from nursing-period data, excluding fault and maintenance episodes.
2. Switch to ROC-focused alarming. Disable or suppress absolute-concentration

ROC analysis is confirmed as the most meaningful discriminator of developing faults, but only when calculated over windows that reflect physical degradation processes

alarms for gases that are chronically elevated, typically H_2, CO, CO_2 and possibly CH_4. Replace them with ROC-based alarms derived from the nursing baseline. Thresholds should normally be tighter than standard values because the transformer is already operating with reduced diagnostic margin.

3. Retain full sensitivity for C_2H_2 and C_2H_4. These gases indicate new or escalating arcing and thermal-fault activity that may not be reflected clearly in elevated H_2 or CO. Their nursing-period baseline is typically near zero or low; any confirmed increase should trigger immediate expert review. The C_2H_2 false-reading caveat still applies and laboratory confirmation remains mandatory.
4. Mandate frequent confirmatory offline DGA. During nursing, confirmatory offline DGA should move from ad hoc confirmation to a scheduled high-supervision regime. A maximum interval of four weeks is recommended during active nursing, with shorter intervals if ROC is non-zero or accelerating.
5. Define escalation criteria. If monitored ROC accelerates by more than 2x compared with the nursing-period average over a 14-day window, or if C_2H_2 or C_2H_4 shows any confirmed increase, the case should trigger outage planning or a formal risk review. The nursing protocol must include explicit go/no-go criteria and a named responsible engineer.
6. Document the nursing decision. The transformer health record should include the date of nursing designation, technical justification, gas levels at nursing onset, revised alarm thresholds, escalation criteria and responsible owner. Without this documentation, future operators may inadvertently normalize a degraded condition.

Nursing is not a long-term solution. It is a risk-managed operational measure intended to defer outage, usually for load or operational reasons, while maintenance, repair or replacement is planned. ODGA in nursing mode provides the earliest warning of deterioration against the established nursing baseline. If the situation cannot be contained within the nursing protocol, the escalation path must lead to a forced or planned outage.

2.2 Fleet deployment checklist

The following checklist provides a practical starting point for implementing the baseline-driven, trend-focused ODGA alarm strategy at fleet scale. All steps should be documented in a fleet ODGA management plan.

Table 12. Fleet ODGA deployment checklist

Step	Action	Standard / technical basis
1	Assign each ODGA monitor a performance tier; verify accuracy and detection limits before activating alarms. Use CIGRE TB 409 Section 7.2 as the field calibration/accuracy-verification procedure for the online device, including synchronized monitor reading, representative sampling at the monitor sampling point, gas-in-oil standard analysis and duplicate-sample repeatability check.	CIGRE TB 783 [5] CIGRE TB 409 Section 7.2 [8]
2	Establish a unit-specific noise floor for each gas; set the minimum detectable change for each monitor individually rather than from manufacturer data sheets alone.	CIGRE TB 783 [5]
3	Define the baseline period: minimum 30-90 days of stable service data, excluding commissioning and oil-processing periods.	IEC 60599 [1]; Part I baseline concept
4	Compute transformer-specific 10th and 90th percentiles; update annually or biannually, or after oil processing or major maintenance.	IEEE C57.104-2019 [2]; Part I percentile framework
5	Configure central analytics for fixed-window ROC; reserve rolling ROC mainly for local HMI visualization and rapid situational awareness.	Part II, Section 1.2
6	Synchronize ODGA timestamps with SCADA using standardized UTC or consistent site-local time to enable laboratory/online overlay.	CIGRE TB 783 [5]
7	Assign each fleet unit to one of three alarm profiles: standard healthy baseline, elevated-stable watchlist, or nursing protocol.	Part II, Section 2.1
8	Establish a fleet-level ROC trend database and compare unit-specific percentiles annually with population statistics to detect systematic drift.	IEEE C57.104-2019 [2]; CIGRE TB 771 [4]

Conclusion

ODGA has matured into a critical element of transformer condition monitoring, but its value depends strongly on how alarm logic is designed and interpreted. This article has shown that directly transferring fixed laboratory-style limits into high-resolution online environments is fundamentally misaligned with both the intent of international standards and the statistical nature of online data. Static ppm thresholds, short-window ROC, and context-free ratio diagnostics tend to increase false positives, accelerate alarm fatigue, and ultimately reduce user confidence in monitoring systems.

A baseline-driven, trend-focused approach offers a more robust alternative. By establishing transformer-specific baselines, using medians and percentiles to describe normal variability, and interpreting exceedances as statistical signals rather than immediate faults, ODGA alarming becomes both more sensitive and more selective. Layering transformer-specific percentiles with IEEE population thresholds and CIGRE guidance further enables graded responses instead of binary alarms.

ROC analysis is confirmed as the most meaningful discriminator of developing faults, but only when calculated over windows that reflect physical degradation processes. Long-window ROC (>=30 days) aligns far better with IEEE and CIGRE methodologies than short-window derivatives. Likewise, fixed-window daily anchoring reduces window-jitter artifacts and produces trends that are more stable, comparable, and operationally meaningful. While rolling ROC remains useful for real-time visualization and rapid situational awareness, it is poorly suited as the primary basis for alarms.

When a transformer is operated under a managed degradation or nursing protocol, the standard alarm philosophy must be adapted: ROC-focused alarming relative to the nursing-period baseline replaces permanent absolute-concentration alarms, C_2H_2 and C_2H_4 sensitivity is preserved, and a defined escalation path with mandatory confirmatory offline DGA forms the safety net.

The emerging best practice is therefore a layered architecture: ODGA devices focus on high-quality measurement and simple real-time indicators, while fleet or central analytics platforms perform fixed-window ROC, baseline management and contextual interpretation. This division of roles improves consistency, reduces nuisance alarms and allows end users to scale ODGA programs across large fleets without overwhelming operators.

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Authors



Dr. Bhaba P. Das is the Regional Manager (Asia Pacific) for Dynamic Ratings Australia, based in Wellington, New Zealand.
He is a Senior Member of IEEE, Young Professional of IEC, Member CIGRE NZ A2 panel, Member of Engineering New Zealand and Executive Editor of Transformer Magazine. He has published 40+ technical articles in various peer reviewed international journals and magazines. He has three patents in New Zealand & Australia related to condition monitoring. He was awarded the Best author award in 2023 and 2025 by voters of Transformer Magazine, a leading worldwide publication on transformers.
He has previously worked at Hitachi Energy Transformers Business Unit in Singapore & ETEL Transformers Ltd in Auckland, New Zealand. He has completed his PhD in Electrical Engineering from the University of Canterbury, New Zealand and Bachelors Degree in Electrical Engineering from University of Gauhati, Assam, India.



Marius Grisaru holds an MSc in Electro-Analytical Chemistry from the Israel Institute of Technology. He has almost 30 years of intense experience in almost all transformer oil test chains, from planning, sampling, and diagnosis to recommendations and treatments, mainly in Israel but also in other parts of the world. He is responsible for establishing test strategies and procedures and creating acceptance criteria for insulating liquids and materials based on current standardization and field experience. In addition, he trains and educates electrical staff on insulating matrix issues from a chemical point of view. He is an active member of relevant Working Groups of IEC, CIGRE, and a former member of ASTM. He is also the author and co-author of many papers, CIGRE brochures, and presentations at prestigious international conferences on insulation oil tests, focusing on DGA, analytical chemistry of insulating oil, and advantageous maintenance policy for oil and new transformers.