

**Accuracy and sensitivity are a MUST for online monitors. However, balance is needed while seeking for perfection without compromising the bigger picture. The focus ultimately needs to be your transformer.**

I've been asked so many times "How many pico-Coulomb can your monitor

detect?" or "What is the minimum pF change you can detect in a bushing?" or "Can your monitor match my laboratory readings?".

Although it is indisputable that we need reliable and accurate monitors, too many times we are focused on small details and we miss the larger scope of the

analysis, which is: what is the condition of my transformer; and what potentially needs to be done? Sometimes the link to these core questions can be lost in the details.

Can a single absolute value from just one reading tell you what you are going to do next? Sometimes yes, more often not.

### Searching for the pico-Coulomb

A 345 kV bushing was monitored online and, after about one year, a Partial Discharge (PD) event of 8 pulses per seconds was detected [1]. It occurred only at that time, never before and never after. At the same time the monitor detected a small

## Are you focusing on

## the RIGHT box?



**Marco Tozzi** received the M.Sc. degree in electrical engineering from the University of Trieste, Italy in 2005 and the Ph.D. degree in electrical engineering from the University of Bologna, Italy in 2010. From 2007 to 2011 Marco was the Project Manager and Technical Advisor at Techimp, Italy, where he was involved in research on diagnostic of insulating systems through Partial Discharges analysis. From 2012 to 2022 Marco was a Product Designer and then Senior Product Manager at Camlin Energy, involved in designing solutions for holistic transformer monitoring. In 2022 he took the role of Sr. Technical Advisor at Camlin Energy, involved in asset diagnostics, consultancy services and optimisation of monitoring and maintenance programs. He is author or co-author of more than 40 technical and scientific papers.

While the 'little box' - your monitor - is important, it is vital to remember that its sole purpose is to give an insight into the 'big box' - your transformer.

increase of capacitance in the same bushings, less than 2%. No one would take an action based on just one of the two pieces of data, but the simultaneous occurrence of the two events suggested a correlation. A DGA test of the oil was done, which confirmed that the bushing had experienced an internal arcing (76 ppm C<sub>2</sub>H<sub>2</sub>),

likely due to a short circuit between two layers.

Would have this action been different if the PD was 1, 100 or 1000 pC? My contention is that it wouldn't. The correlation of data led to the right test and right actions, not the value of the specifics of the data itself. Confidently knowing if there are PDs,

in which winding, bushing, or phase, and whether they are stable over time or not, provides much more information than knowing how many pico-Coulombs.

**Inaccuracies in DGA accuracy**

Table 1 shows the comparison of readings

from an online DGA monitor by two labs. One oil sample was analysed in lab #1, and two samples were analysed in lab #2. The lab data are apparently inconsistent showing variations in both inter-laboratory reproducibility (lab 1 vs. lab 2) and intra-laboratory repeatability (in lab 2).

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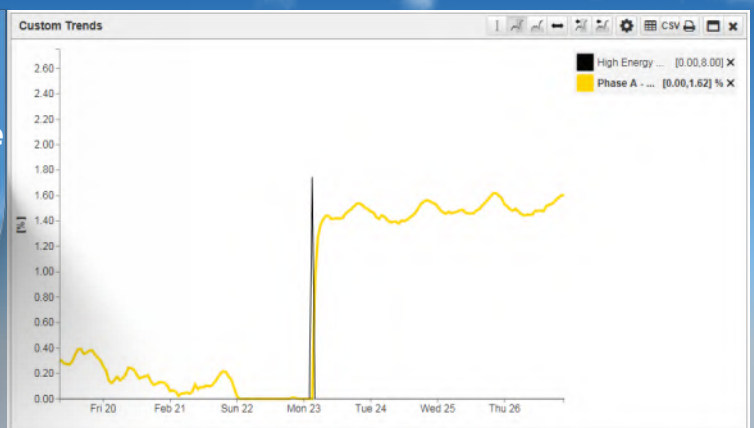


Figure 1. Simultaneous variation of bushing capacitance an PD occurrence

Gas	Online Monitor	Lab 1	Lab 2 Sample #1	Lab 2 Sample #2
H <sub>2</sub>	116	96	140	117
CH <sub>4</sub>	37.6	46.3	47	39
C <sub>2</sub> H <sub>6</sub>	57.8	76.1	70	56
C <sub>2</sub> H <sub>4</sub>	1	1.9	1	2
C <sub>2</sub> H <sub>2</sub>	0	0	<1	<1
CO	268.3	322.2	330	231
CO <sub>2</sub>	2872	3165.1	1802	2067

Table 1. Gas concentrations in ppm. Comparison of DGA monitor readings by two labs

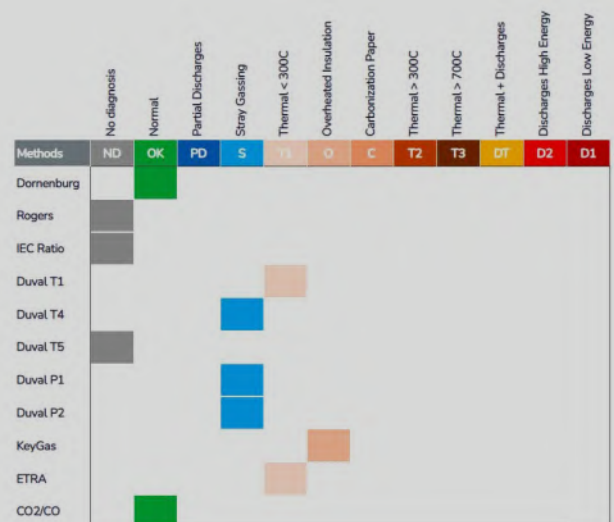


Figure 2. DGA diagnostics using DGA Matrix

Where is the truth? Which lab and which sample shall I use to validate my monitor? The interesting thing is that if you process the data of each column through all the standard diagnostic methods (Figure 2) you will see that all the readings provide the same, identical diagnostic results [2].

Comparing online DGA results with those of a

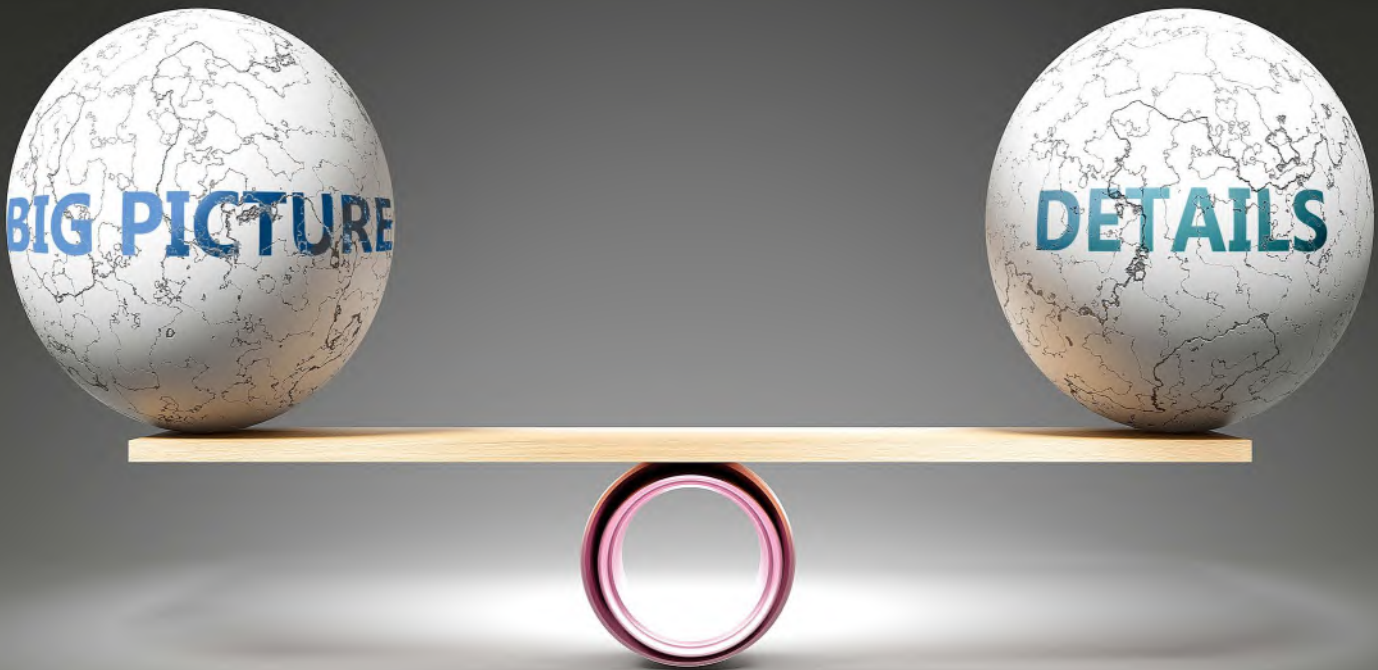
laboratory can be done, but it must be done in a sapient manner, as described in IEC60567 [3] and CIGRE TB783 [4], which can be expensive in terms of time and money. The alternative way of comparing just one single value with a single sample in a single lab will often provide inaccurate results, due to the inaccuracy of the method rather than the data. In the end, what matters

is that the different data sets provide the same diagnostic information.

**Online data could not match offline, but it might be correct**

How many times have you switched off the transformer, taken an offline bushing test and realised that the results are different from those in the online monitor? Is that because the monitor

is inaccurate? It might happen, but most likely, it is because the increase of bushing losses is a complex dynamic process; it can be slow and can be fast, can be permanent or can be intermittent, can be small and can be big. The online monitoring system gives you a real picture of what is happening at real operating conditions. The offline test is an instantaneous snapshot at fixed and



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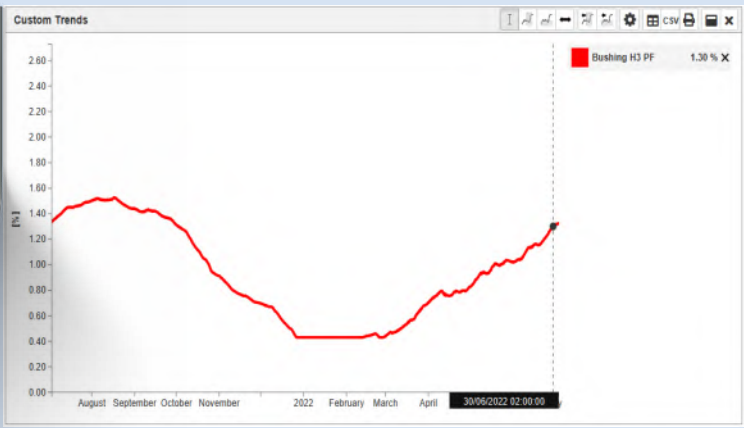


Figure 3. Bushing Power Factor seasonal variation

controlled conditions, and crucially, those may not be the same conditions that are causing the bushing to lose its properties. Figure 3 shows the relative power factor monitored online that is apparently ok in cold season, while it is higher in the hot season. If you test the bushing offline without taking into consideration the oil temperature, you might not see any deviation. But the monitor tells the truth

here, which is that there is a faulty process in the insulation which increases the dielectric losses with temperature. In this case, as expected, the offline test done at ambient temperature showed a value twice the nameplate (0.6%), while the monitor at operating temperature was about four times the nameplate (1.3%). Which one is right? Both are right. And, despite the difference in the absolute

values, there is no doubt that the bushing must be replaced.

While some can still get attracted by the debate on the 1-to-1 comparison of online to offline data, online vs. laboratory data, millivolt versus pico-Coulomb etc., it is key to focus on the right information and not get "lost in the weeds". Very often the most important thing is not the data itself,

but the information given by the correlation of the data, enabling a proactive maintenance program.

**So, the 'little box' is important, but it is vital to remember that its sole purpose is insight into the 'big box' – your transformer.**



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#### References

- [1] M. Tozzi, "Risk Management Requires Actionable Insight: Adding Value with Truly Integrated Transformer Monitoring," *Transformer Technology*, Issue 3, Sept 2019, pp 88-96
- [2] <https://camlingroup.com/en-us/dissolved-gas-analysis-dga-matrix>
- [3] IEC 60567:2011, Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance
- [4] CIGRE TB783, Technical Brochures – DGA monitoring systems