



HYDROCAL by MTE

From concept to proven performance

Luca Züllig, Karsten Schröder, Richard Schomper



A cornerstone of MTE's growth in recent years is its dedicated range of transformer monitoring systems, developed under the HYDROCAL brand

MTE – Swiss precision, German engineering

Since its founding in 1996, MTE Meter Test Equipment AG has stood for reliability, precision, and quality in the field of precision measurement and test equipment.

Rooted in the long-standing Swiss tradition of metrology and tracing its heritage

back to the early days of Landis + Gyr, MTE has grown into a globally recognized company with a comprehensive product range that initially focused on stationary and portable meter test equipment.

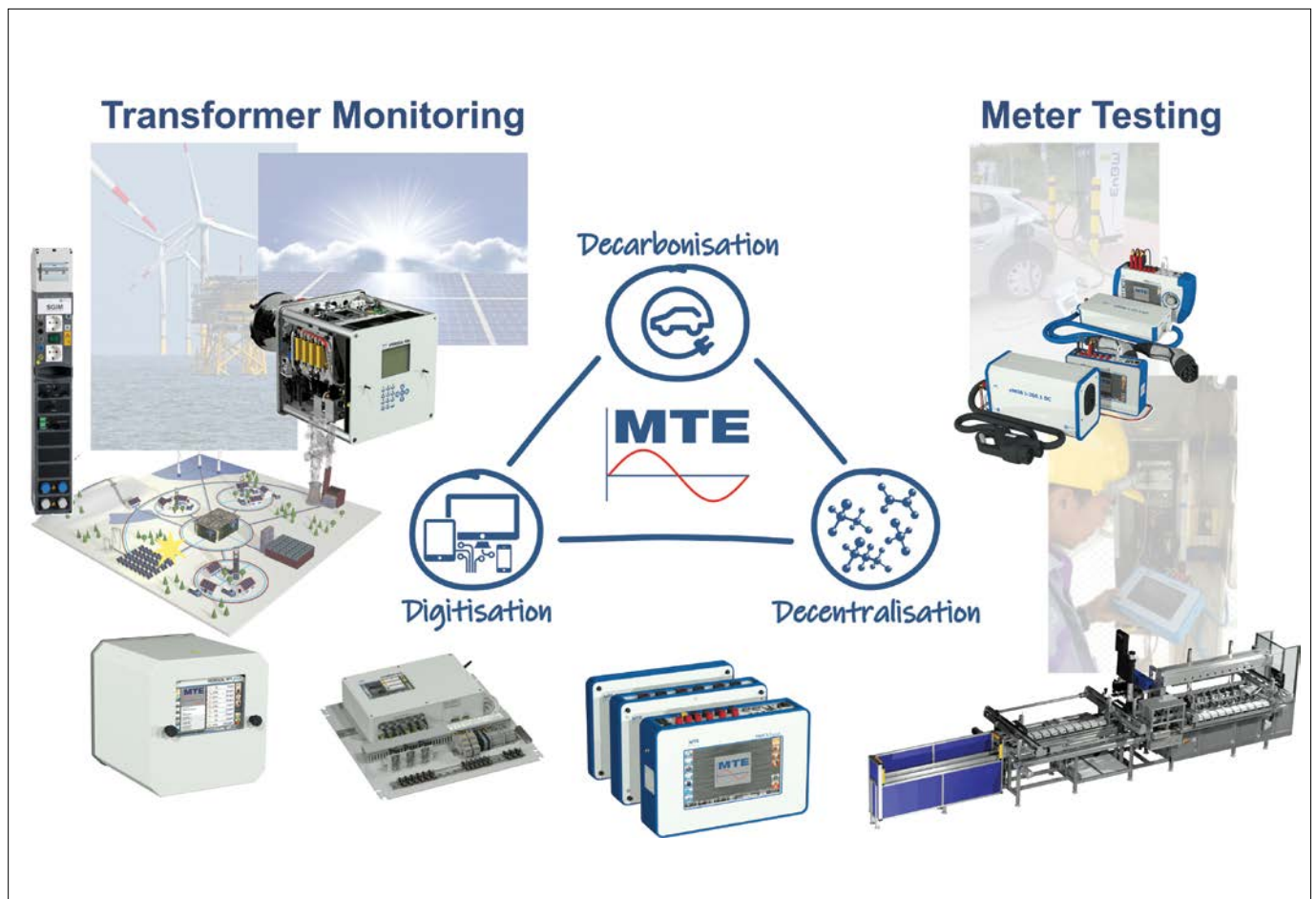
Headquartered in Zug, Switzerland, MTE operates as an internationally active, family-owned SME. The company serves customers in more than 80 countries worldwide, including electric utilities,

metering laboratories, industrial users, and manufacturers of meters and power transformers.

MTE offers a broad and well-established portfolio of precision measurement and monitoring solutions. These include stationary and portable meter test systems, designed for use both in laboratories and on-site, to ensure the accurate verification and calibration of electricity meters. For meter manufacturers, MTE supplies automatic test systems tailored for high-volume environments, enabling efficient and scalable production.

A cornerstone of the company's growth in recent years is its dedicated range of transformer monitoring systems, developed under the HYDROCAL brand. These advanced online devices provide continuous condition assessment through dissolved gas analysis (DGA) and other key parameters, offering critical insights for transformer asset management. The HYDROCAL series has grown into one of MTE's most strategically important innovations and will be explored in greater detail in the sections that follow.

The goal was clear: to develop a compact, reliable, and cost-effective online DGA solution that would allow permanent, unattended monitoring of transformer health



An essential pillar of MTE's quality and innovation strategy is its long-standing production partnership with EMH Energie-Messtechnik GmbH, a German specialist in precision measurement technology. EMH handles most of MTE's manufacturing and development activities. This collaboration ensures robust engineering, precision production, and scalable capacity, all while upholding the high standards MTE customers have come to expect.

Together, MTE and EMH provide a unique synergy combining Swiss innovation and customer orientation with German engineering and manufacturing excellence. This partnership enables MTE to efficiently deliver tailored solutions to customers around the globe, from complex smart meter and smart grid rollouts to critical asset monitoring systems.

MTE maintains a strong global presence through its network of exclusive distributors and its subsidiaries in the UK, India, China, and the United States. The company follows a "global strategy with

The name HYDROCAL derives from the continuous measurement of hydrogen (HYDRO) and the calibration (CAL) of the device itself

local execution" approach, ensuring regional needs are addressed by experienced, on-the-ground partners. As Managing Director Luca Züllig emphasizes: "Our global but local approach, built on long-standing relationships and mutual understanding, enables us to meet demanding requirements and transform challenges into value."

In recent years, MTE has increasingly focused on three global megatrends driving energy transformation: digitalization, decarbonization, and decentralization. These trends have accelerated demand for intelligent, connected measurement and monitoring devices, fueling MTE's growth in smart metering, smart grids, and e-mobility infrastruc-

Origins and early years of HYDROCAL

By the early 2000s, the power transmission sector faced growing challenges: aging transformer fleets, increased network loads, a rapidly decentralizing energy landscape, and reduced maintenance budgets. Luca Züllig, Managing Director, mentions that while talking to industry experts and potential users, MTE found out that "utilities needed tools not only to protect critical infrastructure but also to optimize long-term asset management." Traditional laboratory-based Dissolved Gas Analysis (DGA), with its periodic oil sampling, while effective, could not provide the real-time data and trending analysis required for modern grid demands.



The reliability and simplicity of first-generation HYDROCAL systems made them immediately attractive to grid operators and transformer OEMs

MTE, drawing on its deep metrology expertise and background in precision instrumentation, recognized the opportunity to address this critical monitoring gap. Thus began the company's own transformer monitoring development back in 2001, initiated by MTE in tight cooperation with EMH. The project was led by engineer Karsten Schröder and his team, who would go on to shape MTE's DGA strategy for the next two decades. Referring to the basic vision, Karsten Schröder, Director at EMH, summarizes as follows: "The goal was clear: to develop a compact, reliable, and cost-effective online DGA solution that would allow permanent, unattended monitoring of transformer health, suitable for wider deployment across transformer fleets."

The result was the birth of the very first HYDROCAL, the HYDROCAL 1002. The name HYDROCAL itself reflects the core function and heritage behind the product. As Karsten Schröder, Director at EMH, explains: "The name HYDROCAL derives from the continuous measure-

ment of hydrogen (HYDRO) and the calibration (CAL) of the device itself. Calibration stands for the accuracy and reliability of our measurements, while also referencing our long-standing expertise in precision metrology and legacy products such as the CALPORT 300. It's a bridge between our tradition in meter testing and our innovation in transformer diagnostics."

From the beginning, HYDROCAL devices were designed for ease of use and longevity. The first HYDROCAL units focused on the continuous online detection of hydrogen and moisture, which are among the earliest indicators of thermal or electrical faults in transformer insulation systems. These compact devices could be installed quickly via a single transformer valve and required no carrier gases or recalibration. Thanks to their robust mechanical design, they operate reliably even in harsh outdoor environments – withstanding extreme heat, humidity, dust, and cold. These core characteristics remain hallmarks of the HYDROCAL family to this day.

Developing HYDROCAL was both a technological and organizational challenge. MTE had to combine chemical gas analysis, long-term sensor stability, and rugged industrial design into a compact system that could be easily mounted and operated continuously on energized transformers. Reflecting on the pioneering days of HYDROCAL, Luca Züllig, Managing Director, notes: "Creating the first HYDROCAL devices meant venturing into new territory, both technically and as a company. But we were able to build on our proven strengths – precision, reliability, market access, and a deep understanding of electrical measurement – to bring a robust and forward-looking solution to the transformer market."

The early HYDROCAL models used membrane-based gas extraction combined with capacitive humidity sensors, establishing a proven and low-maintenance foundation. The reliability and simplicity of these first-generation systems made them immediately attractive to grid operators and transformer OEMs – particularly for smaller power transformers, which had previously been overlooked for online DGA due to cost and complexity. By providing continuous, real-time insights, HYDROCAL enabled utilities to shift from reactive maintenance to a predictive, condition-based strategy – unlocking additional operational advantages. The benefits of moving from manual sampling to online DGA were widely recognized:

Recognizing the need for a truly maintenance-free, high-performance solution, MTE achieved a significant breakthrough between 2018 and 2020



- Early fault detection through continuous trend monitoring
- Reduced risk of unplanned outages and costly transformer failures
- Minimized on-site maintenance, lowering operational burden
- Strategic, fleet-wide visibility of transformer health and asset prioritization

As market adoption grew, so did MTE's commitment to innovation. What began as a targeted solution to improve distribution grid reliability quickly evolved into a broader product family, driven by consistent engineering, field validation, and customer feedback. Over time, the HYDROCAL line steadily advanced while integrating new technologies that enhanced diagnostic accuracy, operational reliability, and ease of deployment.

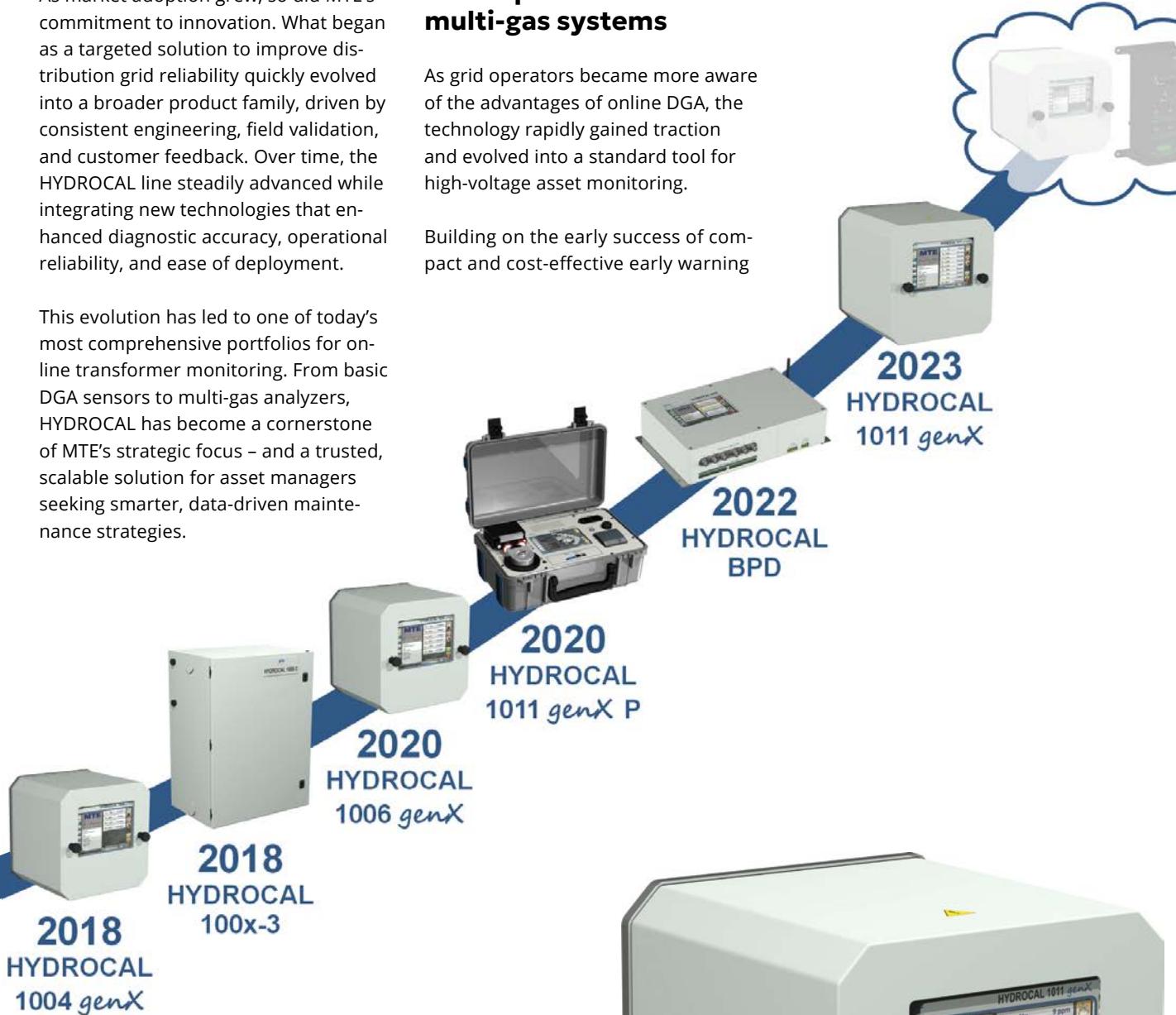
This evolution has led to one of today's most comprehensive portfolios for on-line transformer monitoring. From basic DGA sensors to multi-gas analyzers, HYDROCAL has become a cornerstone of MTE's strategic focus – and a trusted, scalable solution for asset managers seeking smarter, data-driven maintenance strategies.

The shift toward more advanced transformer diagnostics materialized with the launch of the HYDROCAL 1005, MTE's first multi-gas unit

Development of the first multi-gas systems

As grid operators became more aware of the advantages of online DGA, the technology rapidly gained traction and evolved into a standard tool for high-voltage asset monitoring.

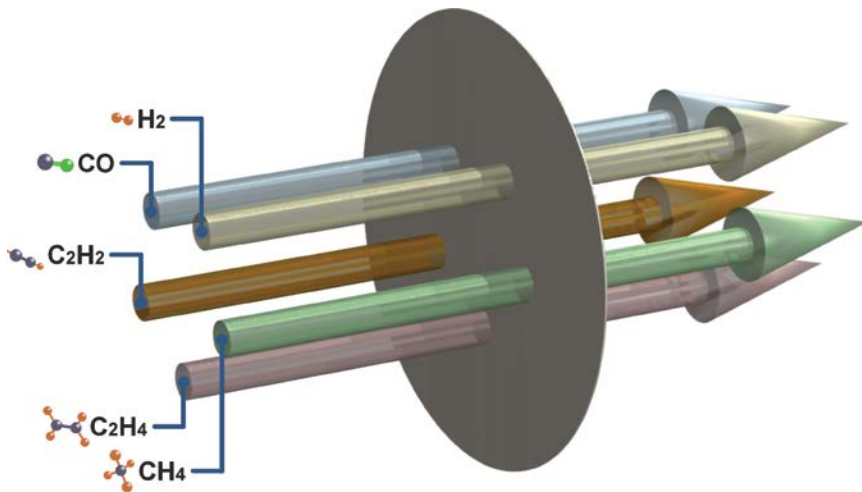
Building on the early success of compact and cost-effective early warning



The HYDROCAL 1011 genX – the new flagship of the HYDROCAL genX family and the most advanced multi-gas online DGA system developed by MTE to date



HYDROCAL 1011 genX



Copolymer Membrane of HYDROCAL 1004/1006 genX

systems such as the HYDROCAL 1002 and its successor, the HYDROCAL 1003, MTE set its sights on advancing transformer diagnostics to a higher level of precision and additional data. Recognizing the need for more sophisticated monitoring of critical and strategically important power transformers, the company expanded its focus toward multi-gas DGA systems – what could be seen as “intensive care” solutions for high-value assets.

This strategic shift marked a turning point in the evolution of the HYDROCAL portfolio. What initially began with basic hydrogen (H₂), moisture (H₂O) and carbon monoxide (CO) detection soon developed into a full-fledged platform

capable of individual analysis of up to totally eight key gases, including carbon dioxide (CO₂), methane (CH₄), acetylene (C₂H₂), ethylene (C₂H₄), ethane (C₂H₆), and even oxygen (O₂).

The shift toward more advanced transformer diagnostics materialized with the launch of the HYDROCAL 1005, MTE’s first multi-gas unit. This was soon succeeded by the HYDROCAL 1008 and 1009, with each model pushing the boundaries further in terms of measurement capability, system durability, and analytical depth.

A key enabler of this leap forward was the adoption of advanced near-infrared (NIR) spectroscopy in combination with

the industrial-scale application of the headspace gas extraction principle – a true technological breakthrough. It enabled high-resolution, selective gas analysis while eliminating the need for consumables such as carrier or calibration gases, resulting in an easy to install, robust, and cost-effective solution for long-term transformer fleet monitoring.

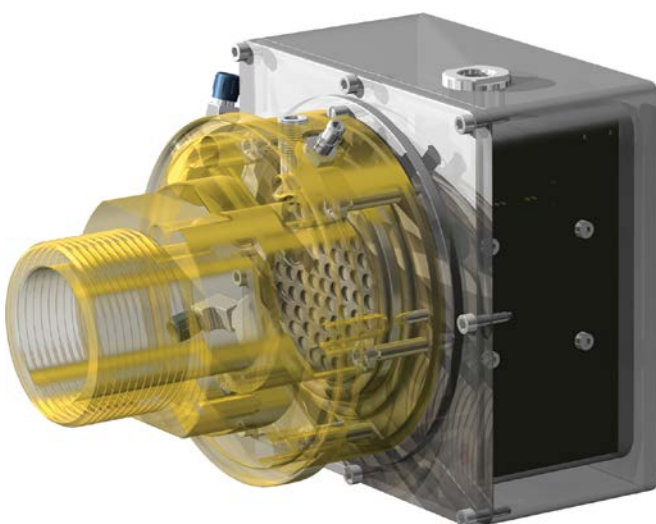
As Richard Schomper, Product Manager of Transformer Monitoring at MTE, explains: “Our ambition was to provide utilities not just with data, but with actionable diagnostics. By expanding beyond early warning systems, HYDROCAL evolved into a toolset capable of monitoring the most critical transformers in real time – reliably, accurately, and without the hidden costs of consumables or recalibration.”

Launching a new generation: HYDROCAL genX

Despite the progress achieved with earlier multi-gas DGA systems, one common challenge remained across most solutions on the market: relatively high maintenance requirements. These were often the result of either the gas analysis technology employed – such as the need for periodic replacement of carrier and calibration gas cylinders in chromatographic systems – or the complexity and wear-prone nature of moving mechanical components used in, for instance, photoacoustic spectroscopy, including pumps, compressors, valves, and chopper wheels.

Recognizing the need for a truly maintenance-free, high-performance solution, MTE achieved a significant breakthrough between 2018 and 2020. The foundation of this advancement was the industrial-scale implementation of a modified PTFE membrane incorporating a special copolymer, which offered the required permeability and selectivity to extract a broader range of dissolved gases. This innovation enabled the use of a proven membrane extraction technique in combination with MTE’s advanced near-infrared (NIR) spectroscopy for gas analysis.

The first products to feature this approach were the HYDROCAL 1004 genX and, later, the HYDROCAL 1006 genX. These devices



Membrane and NIR-Cell of HYDROCAL 1004/1006 genX

es offered precise online monitoring of key fault gases, with no moving parts, no consumables, and a mechanically robust design. Earlier limitations of Teflon (PTFE)-based membranes, which restricted detection to gases like hydrogen (H_2) and carbon monoxide (CO), were now resolved. The 1004 genX focused on detecting hydrogen (H_2), carbon monoxide (CO), and acetylene (C_2H_2), while the 1006 genX added ethylene (C_2H_4) and methane (CH_4) – enabling advanced diagnostics in accordance with IEC 60599 using methods like the Duval Triangle and Rogers' Ratios. In the genX series, NIR spectroscopy is used to identify individual gases by detecting their unique absorption spectra in the infrared range. Meanwhile, hydrogen (H_2) measurement continues to rely on a high-sensitivity silicon oxide (SiO_2) sensor, ensuring precise and consistent detection. In addition to the gas analysis, all HYDROCAL genX models are also equipped with a capacitive oil moisture sensor that measures both absolute (%) and relative (ppm) moisture levels in the transformer oil – providing critical insight into the condition of the insulation system.

Extending proven technology: From offline portable to online flagship

In the past several years, MTE received inquiries from the market for a portable dissolved gas analysis (DGA) solution – a flexible, mobile alternative to permanently installed online DGA monitors. Utilities and service providers are increasingly challenged by delays and rising costs associated with traditional laboratory-based DGA, and the demand for faster, on-site diagnostics to support a broader range of steadily growing field applications. “Customers needed a solution that delivers laboratory-quality results directly at the transformer, without the logistical effort and turnaround time of sending oil samples to a lab,” explains Richard Schomper, Product Manager for HYDROCAL at MTE. “Our goal was to provide a compact, field-ready instrument that combines ease of use, accuracy, and reliability – and could serve as a true alternative to conventional offline analysis.”

In response to this need, MTE developed the HYDROCAL 1011 genX (P)ortable – a full-range, multi-gas offline DGA analyzer

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HYDROCAL 1011 genX Portable

designed to deliver laboratory-grade results in the field. This compact, maintenance-free device combines advanced near-infrared (NIR) spectroscopy with a headspace-based gas extraction system, offering high-precision detection of moisture (H_2O) and ten key gases dissolved in transformer oil, adding nitrogen (N_2) and propane (C_3H_8) to the already available range of key gases of previous HYDROCAL devices.

The success and field-proven reliability of the HYDROCAL 1011 genX P set the stage for the next step in product development. This evolution led to the introduction of the HYDROCAL 1011 genX – the new flagship of the HYDROCAL genX family and the most advanced multi-gas online DGA system developed by MTE to date. Designed for continuous monitoring of critical transformer assets, the 1011 genX

delivers full-spectrum gas diagnostics using the same proven measurement principles, but in a format suitable for permanent installation.

“Our goal was to take everything that made the 1011 genX Portable so effective – its diagnostic depth, robustness, and ease of use – and bring it into a fully online system capable of supporting the continuous demands of critical infrastructure,” says Luca Züllig, Managing Director of MTE. “The HYDROCAL 1011 genX embodies our philosophy of precision without compromise – reliable, accurate, and built for real-world conditions.”

The system combines advanced near-infrared (NIR) spectroscopy with a compact, membrane-free headspace extraction system, reducing and eliminating traditional vulnerabilities like moving parts and consumables. The result is a

In the future, nearly all transformers – regardless of voltage class – will be delivered with integrated monitoring systems

high-resolution monitoring solution that provides real-time insights into transformer health.

Karsten Schröder, Director at EMH and the original innovator behind HYDROCAL, adds:

“With the 1011 genX, we’ve achieved something truly unique – a full-range online DGA system that measures ten individual gases and moisture in oil, with minimal maintenance overhead. It’s the culmination of over two decades of development, shaped by field experience and engineered for the next generation of grid monitoring.”

Expanding the scope: HYDROCAL BPD – bushing and partial discharge monitoring

As transformer condition monitoring evolves, it has become increasingly important to also address failures outside

the transformer main tank. According to the CIGRÉ Working Group A2.37 Transformer Reliability Survey (Brochure 642), approximately 25% of transformer failures are linked to bushing defects – many of which result in catastrophic outcomes, including fire or even complete asset loss.

To address this risk, MTE developed the HYDROCAL BPD – an advanced online monitoring system dedicated to high-voltage bushings and partial discharge (PD) detection. This modular platform can function as a standalone unit or be fully integrated with the broader HYDROCAL DGA family, providing grid operators with a unified, full-spectrum transformer condition monitoring strategy.

“With HYDROCAL BPD, we wanted to close the gap between bushing diagnostics, partial discharge detection and dissolved gas analysis,” explains Richard Schomper, Product Manager at MTE. “Bushing failures are often sudden and

catastrophic, so integrating PD and capacitance monitoring into our ecosystem gives operators the real-time insight they need to act before it’s too late.”

The HYDROCAL BPD system supports:

- Voltage and phase angle measurements at the bushing test tap to calculate capacitance (C) and $\tan \delta$ / power factor (PF)
- Electrical partial discharge (PD) detection via the test tap, in accordance with IEC 60270
- Ultra-High Frequency (UHF) PD measurements for detecting activity within the transformer’s active part, through dielectric windows or via the oil drain valve

This dual-monitoring capability enables precise diagnostics of insulation aging and electrical stress – two key failure mechanisms that often evolve undetected over time.

Data from the HYDROCAL BPD can be easily integrated into existing SCADA or substation automation systems via standard protocols including MODBUS (RTU/ASCII and TCP), DNP3.0, and IEC 61850. For advanced evaluation, the system includes the HYDROCAL Hybrid APP – a comprehensive software tool for data visualization, trend analysis, and alarm management.

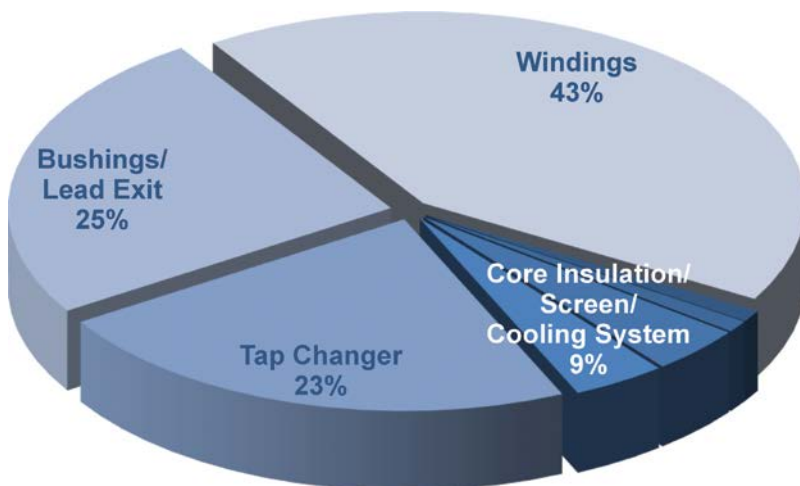
By combining online DGA, bushing monitoring, and PD detection in a single cohesive system, MTE offers asset managers a comprehensive and modular solution for safeguarding some of the most failure-prone components in high-voltage transformers.

The future of transformer monitoring

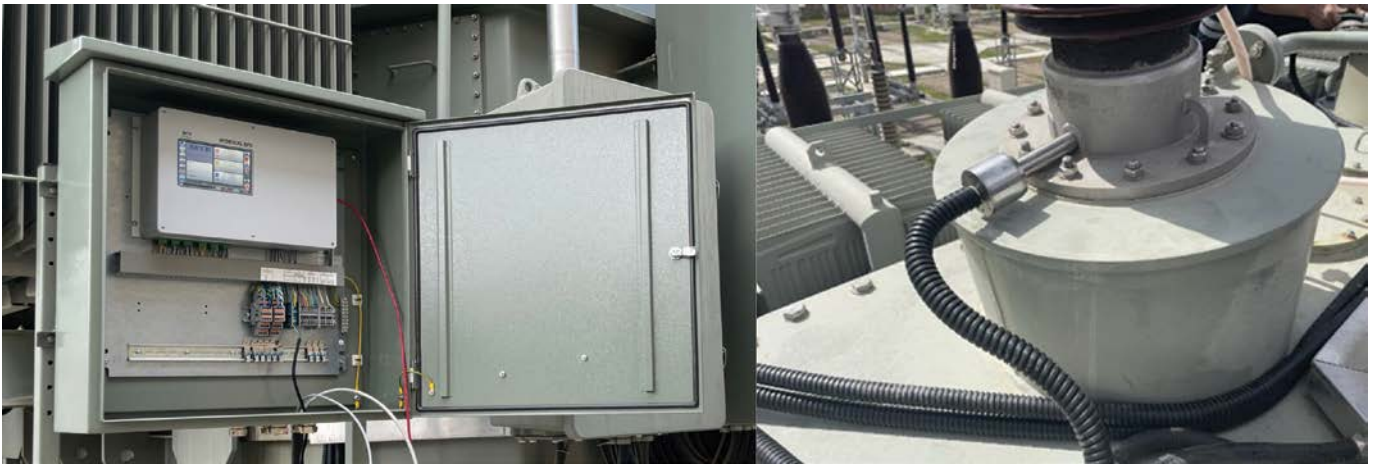
The transformer monitoring landscape is evolving rapidly – driven by the convergence of digitalization, electrification, smart grid integration, and even AI-powered predictive analytics. What was once considered optional for high-voltage assets is increasingly becoming standard across the entire transformer fleet.

“In the future, nearly all transformers – regardless of voltage class – will be delivered with integrated monitoring

As transformer condition monitoring evolves, it has become increasingly important to also address failures outside the transformer main tank



CIGRÉ Working Group A2.37 Transformer Reliability Survey (Brochure 642)



systems,” notes Richard Schomper, Product Manager at MTE. “What varies is the combination of monitoring functionalities tailored to the asset’s criticality and application.”

Typical transformer monitoring systems will increasingly include one or a combination of the following elements:

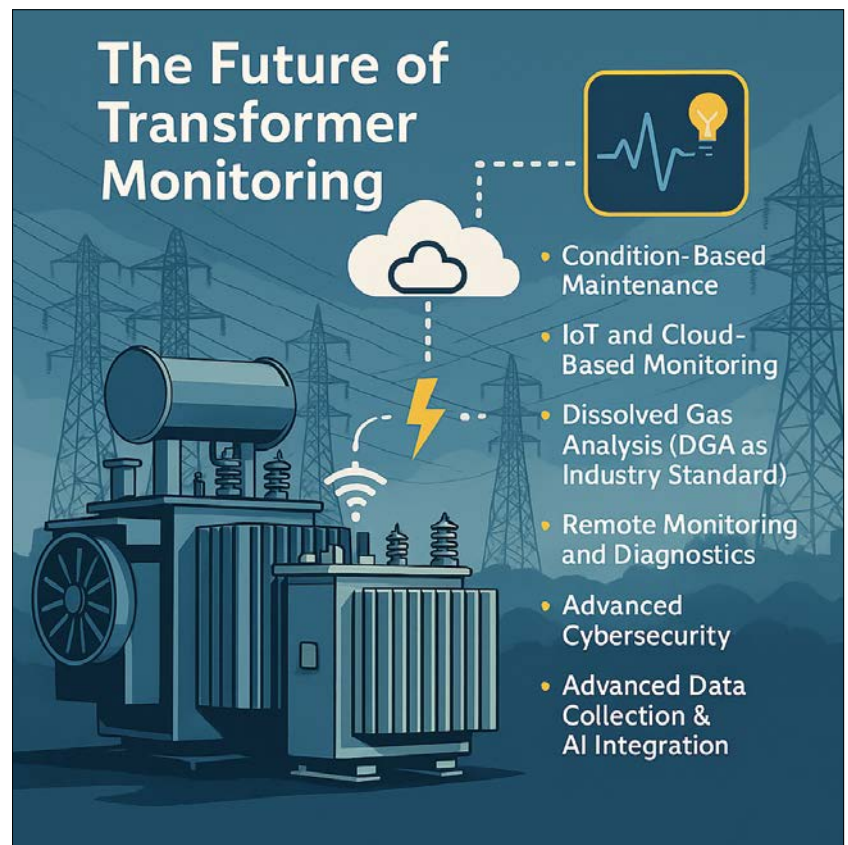
1. Online Dissolved Gas Analysis (DGA)
 - Continuous gas monitoring in transformer oil
 - Early detection of arcing, overheating, or insulation degradation
2. Thermal Monitoring
 - Measurement of top oil and winding temperatures
 - Estimation of hot-spot aging and thermal stress
3. Bushing Monitoring
 - Tracking of bushing capacitance and power factor ($\tan \delta$)
 - Detection of deterioration and partial discharge (PD) activity
4. Partial Discharge Monitoring
 - Detection of high-frequency discharges across insulation barriers
 - Early fault detection in bushings and transformer windings
5. Moisture and Oil Quality Monitoring
 - Monitoring of water content, dielectric strength, and oil aging
 - Assessment of insulation condition and service readiness
6. Load and Voltage Monitoring
 - Measurement of load currents, tap changer operations, and voltages
 - Optimization of performance and overload protection
7. Integrated Condition Monitoring Platforms
 - Multi-sensor systems with dashboards, alarms, and diagnostics

MTE developed the HYDROCAL BPD – an advanced online monitoring system dedicated to high-voltage bushings and partial discharge (PD) detection

- Support for predictive maintenance and asset management strategies

These functionalities are accelerating a shift across utilities toward Condition-

Based Maintenance (CBM). Rather than relying on fixed inspection intervals, grid operators are adopting real-time data-driven strategies that minimize risk and optimize asset life cycles.



MTE's HYDROCAL product family – DGA, BPD, and, in the future, DTM (Distribution Transformer Monitoring) systems – is at the core of enabling this transition.

Contributing to this transformation is the rise of IoT and cloud-based solutions. The integration of IoT sensors with secure cloud platforms is enabling remote diagnostics, centralized fleet visibility, and scalable analytics. MTE's HydroSOFT Hybrid App is already leading in this space, with a cloud-enabled version soon to be released.

At the same time, DGA has solidified its role as the standard method for early fault detection, and MTE now offers the industry's largest portfolio of DGA solutions – ranging from portable analyzers to advanced, multi-gas online systems.

In parallel, remote monitoring capabilities are being expanded through modern communication interfaces, allowing real-time transformer diagnostics without the need for on-site inspection. All current HYDROCAL systems are built with this functionality in mind.

Recognizing the growing threat of cyberattacks in digital substations, MTE has also prioritized cybersecurity. By selecting SQL Server as the foundation for its monitoring software and integrating enhanced security hardware into devices like the HYDROCAL BPD, DTM, and the upcoming 1003 genX, MTE is proactively safeguarding critical infrastructure.

Finally, the role of artificial intelligence in transformer monitoring is set to expand. Modern systems are increasingly leveraging automated insights and pattern recognition, enabling predictive maintenance and smarter operational planning across entire transformer fleets.

“Ultimately, these developments are making transformer monitoring more reliable, effective, and cost-effective,” says Richard Schomper, Product Manager at MTE. “They're key to improving grid resilience and avoiding unexpected transformer failures in tomorrow's smart networks.”

Ultimately, these developments are making transformer monitoring more reliable, effective, and cost-effective

Authors



Luca Züllig is the Managing Director of MTE Meter Test Equipment AG guiding the company's strategic growth and international expansion. Luca holds a Master of Arts (M.A. HSG) in Marketing, Services, and Communication Management from the University of St. Gallen in Switzerland, where he also earned a diploma in Business Education and completed an Advanced Management Program (CAS). Before joining MTE, Luca worked as a business consultant managing international projects across industries such as energy, medical technology, electronics and machinery. At MTE Luca actively engages with the global sales team, organizing seminars and forums across regions such as Europe, India, and the Asia-Pacific, fostering innovation and strengthening distribution partnerships.



Karsten Schröder is a Senior Sales Manager for MTE Meter Test Equipment AG and Director of EMH Energie-Messtechnik GmbH. Karsten received a master's degree in electrical engineering from the University of Bremen in Germany, where he specialized in Automation Technology. He started MTE's development of Online Dissolved Gas Analysis products in 2001 with the first products introduced in 2004.

Karsten's responsibility includes definition of product strategies and R&D project management, besides being responsible for the sales management of some key markets (e.g., India, USA). Karsten's technical experience includes membership in the German DKE UK182 for Fluids and Gases for electrotechnical applications. He holds patents and has authored papers in the field of Online Dissolved Gas Analysis, e.g. within CIGRÉ. He is a member of CIGRE working group JWG D1/A2.77 Liquid Tests for Electrical Equipment and JWG A2/D1.67 Guideline for Online Dissolved Gas Analysis Monitoring.



Richard Schomper is the Product Manager of Transformer Monitoring for MTE Meter Test Equipment AG and also the Area Sales Manager for several West- and Central European Countries like the Netherlands, Belgium, France, Poland, Slovakia, and Czech Republic. Richard holds a Master of Science in High Voltage Technology & Management from the Technical University of Delft in the Netherlands. Before joining MTE, Richard worked for almost 20 years for Haefely AG as a Transformer Specialist in different roles, starting as a young Technical Application Engineer, to become a Product Manager, Project Manager, and slowly venturing more into Sales, becoming a Sales Manager and Business Development Manager. At MTE Richard supports his sales colleagues and customers with technical knowledge, presentations and other marketing material for the complete HYDROCAL Transformer Monitoring Product Line, while continuously improving the products and gaining valuable insights from the transformer market and its customers.