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Advancing Underground Network Transformer Monitoring

April 2026 | Joe Rusin, Vice President,
Transformer System Sales, H2scan

When asked about the current condition of their underground network transformer fleet, most utility operations managers must admit that they don't know. Across major metropolitan areas, thousands of network transformers deliver power to critical services, businesses, and residents while housed as part of an underground infrastructure. Condition monitoring of these vault transformers through periodic transformer oil sampling remains operationally impractical, logistically challenging, and prohibitively expensive.

The consequences are measurable. Transformer failures that could be detected months in advance through continuous monitoring instead occur without warning. These transformer failures can escalate into fires, compromise multiple transformers, disrupt service to thousands of customers, and create hazardous conditions for emergency response crews. Industry data shows the timeline from start of gassing to transformer failure averages six months, yet manual oil sampling occurs annually at best and in many cases, not at all.

The monitoring gap stems from fundamental operational challenges. Network transformers operate in hostile vault environments: confined spaces subject to heavy loading, elevated temperatures (exceeding 100°C), water infiltration, and debris accumulation. Accessing these confined vault spaces requires coordinated outages, vault preparation, confined space protocols and subsequent laboratory analysis of the oil sample. This entire process stretches maintenance budgets, and as fleet sizes grow and vault access becomes more difficult, monitoring stresses overworked maintenance crews.

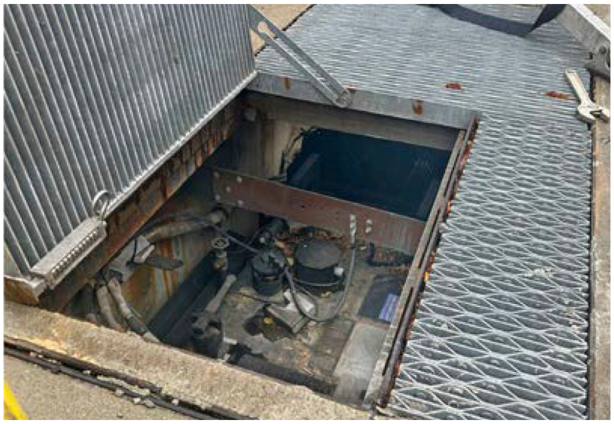
The Underground Network Monitoring Challenge

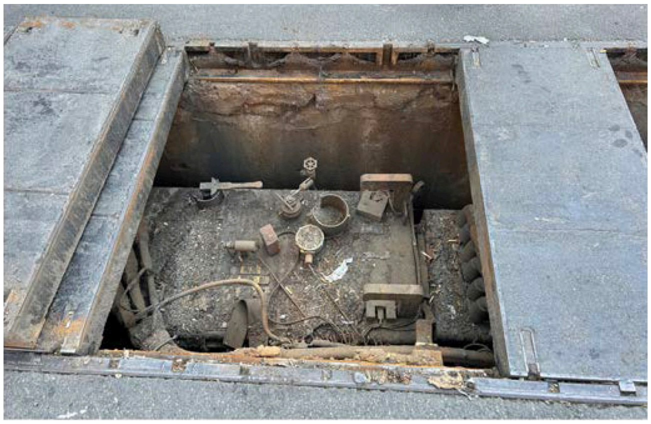
Network transformers are subject to operational stresses that distinguish them from standard substation equipment. Heavy loading in confined vault spaces can raise transformer oil temperatures. These conditions accelerate the thermal degradation of insulating materials, producing hydrogen gas as the primary indicator of developing faults.

Unlike above-ground transformers, for which periodic dissolved gas analysis can be performed cost-effectively, accessing underground network transformers for manual sampling poses significant logistical and safety challenges.

Traditional monitoring solutions designed for substation transformers cannot withstand the extreme conditions found in network vaults. The combination of high ambient temperatures, elevated hydrogen concentrations during fault conditions and exposure to moisture creates an environment that damages standard monitoring sensors. Additionally, the economics of network transformer monitoring have historically been prohibitive—with hundreds of network transformers in a typical urban grid, the cost per unit must remain reasonable while providing reliable data.

Hydrogen is the first and most reliable fault gas, appearing before other gases during incipient fault development. However, monitoring hydrogen in network transformers requires sensors capable of measuring both absolute hydrogen levels, which can reach concentrations that would damage conventional sensors, and the rate of hydrogen generation, which provides critical early warning of developing abnormalities.





Vault transformers are often in a hostile location, making maintenance and testing difficult.

Purpose-Built Monitoring System

H2scan Corporation's HY-VAULT™ Underground Transformer Monitoring system addresses these challenges through an integrated solution combining the GRIDSCAN® 5015 hydrogen sensor with the AVO-1 interface device. The GRIDSCAN 5015 was engineered specifically for the extreme conditions encountered in network transformers, with a measurement range extending from 250 PPM to 50,000 PPM and continuous operation capability at temperatures up to 80°C. This extended range proves essential in network applications where hydrogen concentrations during fault conditions far exceed levels found in typical substation transformers.

The system employs patented self-calibration technology that eliminates sensor drift and the need for periodic calibration. The sensor's proprietary integrated circuit, paired with field-proven solid-state sensing elements, provides reliable hydrogen detection in environments where conventional electrochemical sensors would fail or require frequent replacement.

The AVO-1 interface device extends monitoring capability to previously inaccessible vault locations. Network transformer vaults often lack the communications infrastructure available in substations, requiring monitoring solutions that can operate with limited connectivity while still providing actionable data to system operators. The AVO-1 addresses this gap, enabling data collection and transmission from remote underground locations while maintaining the IP rating necessary for reliable operation in humid vault environments.

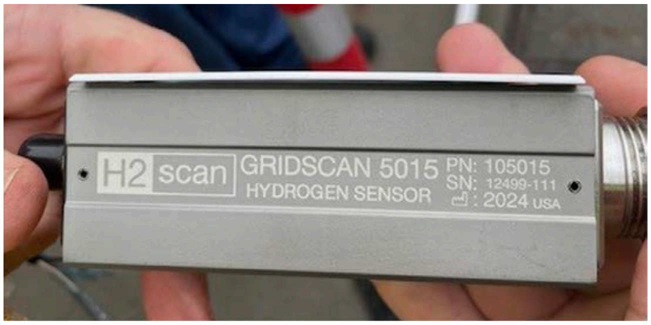
HY-VAULT offers operators marine-grade corrosion resistance for reliable operation in the harshest vault conditions. Rapid deployment allows installation and commissioning in hours rather than weeks, while connectivity options, including Modbus and analog outputs, enable seamless integration with existing utility infrastructure.

Technical Implementation and Benefits

The HY-VAULT system provides continuous monitoring that has the capability to alert network operations teams to incipient faults as they develop, rather than after catastrophic failure occurs. By tracking both absolute hydrogen levels and rate of change, the system enables operators to distinguish between normal thermal hydrogen generation, which increases gradually under load, and accelerating fault conditions that require immediate attention. This dual-measurement approach reduces false alarms while ensuring genuine fault conditions trigger an appropriate response.

Installation of the HY-VAULT system integrates with existing network transformer infrastructure without requiring extensive modifications. The sensor mounts directly to the transformer, eliminating the need for complex sampling systems or additional vault penetrations. This straightforward installation reduces deployment costs and minimizes service interruptions during system commissioning.

The system's data enables utilities to transition from reactive maintenance—responding to failures after they occur—to predictive maintenance strategies based on actual equipment condition. Operations teams can prioritize field interventions based on real data rather than age-based replacement schedules, optimizing resource allocation while improving system reliability. When hydrogen trends indicate developing problems, transformers can be de-energized and removed during planned outages rather than emergency response situations.



Addressing Industry-Wide Infrastructure Challenges

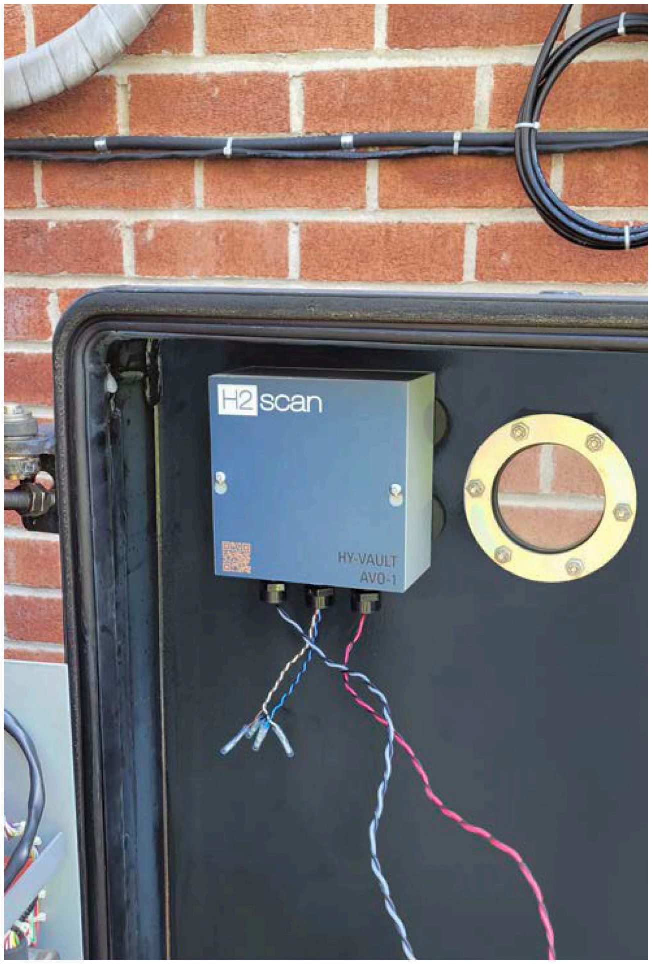
The timing of viable network transformer monitoring solutions coincides with mounting pressures on utility operations. Workforce shortages across the electric utility industry compound the challenges of maintaining aging infrastructure through labor-intensive manual processes. Supply chain constraints have created unprecedented lead times for transformer procurement, with reports indicating delivery times of 30 to 100 weeks for new units. Multiple factors contribute to these delays:

- surging demand driven by renewable energy integration
- data center expansion
- increasing electrification
- raw material constraints
- manufacturing capacity limitations

In this environment, the traditional "run to failure" operational approach becomes untenable. Every transformer failure not only triggers immediate emergency response costs but also potentially initiates a two-year wait for replacement equipment. Network transformer failures often affect multiple adjacent units and associated infrastructure. Vault fires can damage cables, switchgear, and nearby transformers, multiplying repair costs and extending restoration timelines.

Early detection of transformer faults significantly improves personnel safety by reducing exposure to hazardous conditions. Field crews responding to transformer failures face risks from electrical arcs, hot gases, and fire. Continuous monitoring enables proactive intervention before conditions escalate to catastrophic failure, allowing maintenance work to proceed under controlled conditions rather than in emergency situations.

System operators gain visibility into transformer fleet condition that previously required periodic manual testing—a process that is both labor-intensive and potentially hazardous due to vault access requirements. Continuous data collection provides trend information that manual snapshots cannot capture, revealing gradual degradation patterns that might otherwise go unnoticed until failure.



Modern Solutions for an Age-Old Problem

For the first time, an underground monitoring system offers a solution to the unique challenges of vault environments through purposefully designed and manufactured technology. The HY-VAULT system provides utilities with a cost-effective means of protecting critical infrastructure, improving operational safety, and transitioning to predictive maintenance strategies. As urban networks continue supporting increasing load density and reliability requirements, continuous transformer monitoring establishes a foundation for more resilient power delivery systems.

For utilities operating network systems, the question has shifted from whether to monitor network transformers to how quickly monitoring can be deployed across the fleet. The combination of proven solid-state sensing technology, maintenance-free operation and integration capabilities positions continuous transformer monitoring as a standard practice for modern network operations—one that enhances both safety and reliability while reducing total cost of ownership through avoided failures and optimized maintenance strategies.

About H2scan

H2scan, a pioneer in the development of hydrogen sensor technology, has been at the forefront of innovation for more than two decades. Building on a strong foundation of research and development, including proprietary solid-state technology pioneered at Sandia National Laboratory and the U.S. Department of Energy, H2scan has established itself as the preferred provider of leading hydrogen sensors, analyzers, and systems. The operating life of its sensors surpasses that of other commercially available systems, and the company's new Gen.5 solutions with self-calibration offer unparalleled accuracy, maintenance-free operation and cost-effectiveness.

Trusted by industry giants, like ABB, ExxonMobil, NASA and others its products are integral in shaping the new Hydrogen Economy for a clean, secure, and affordable energy future. With sensors deployed across all six continents in 190 countries, H2scan products protect more than $3.2 billion in transformer assets. Our comprehensive monitoring solutions are used by power utilities for transformer fleet monitoring, by the petroleum and chemical industries to optimize hydrogen-based processes, and for safety monitoring in enclosed areas susceptible to hydrogen leaks.

H2scan's proprietary self-calibration technology delivers the clean, reliable data that AI and predictive maintenance initiatives demand—eliminating costly data cleanup while protecting current operations. Tomorrow's winners are collecting accurate data today. H2scan holds 40 patents covering its core technology, software, and product innovations.

For more information, visit www.h2scan.com.