

The evolution of transformer reliability and maintenance and the relationship to monitoring and diagnostic technology

by **Todd Hurst**

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THE MID-20TH CENTURY SAW THE INTRODUCTION OF DGA (DISSOLVED GAS ANALYSIS) AS A POWERFUL DIAGNOSTIC TOOL FOR ASSESSING THE CONDITION OF TRANSFORMER INSULATION. DGA INVOLVES ANALYZING GASES DISSOLVED IN TRANSFORMER OIL TO DETECT AND IDENTIFY INCIPENT FAULTS SUCH AS OVERHEATING, ARCING, AND PARTIAL DISCHARGES. THIS TECHNIQUE REVOLUTIONIZED TRANSFORMER DIAGNOSTICS, ENABLING EARLY DETECTION OF POTENTIAL ISSUES AND PROACTIVE MAINTENANCE STRATEGIES.



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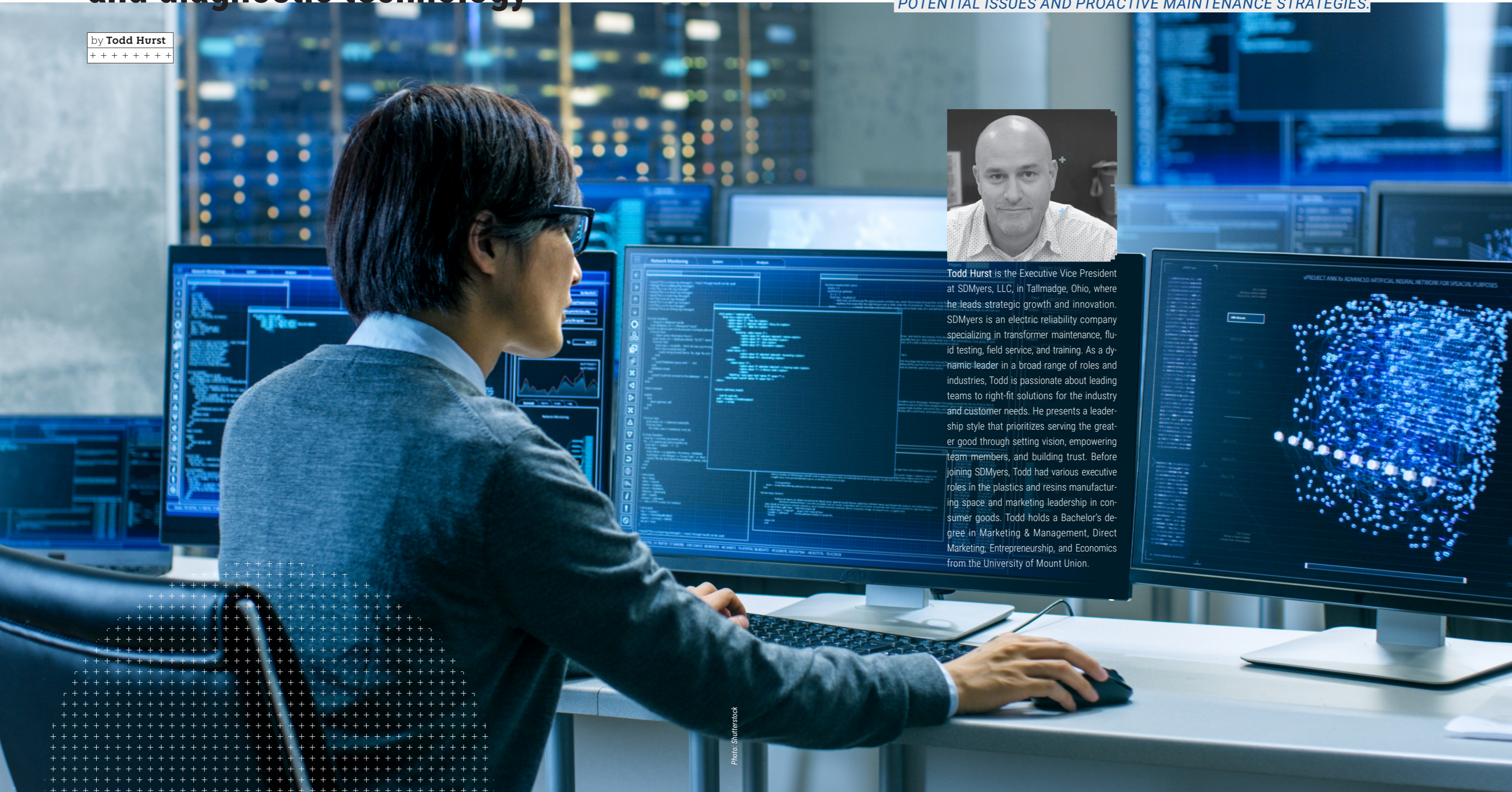


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Some History

The evolution of monitoring and diagnostic technology for liquid-filled transformers has been marked by significant advancements driven by technological innovations and

These inspections were limited in scope and effectiveness, often requiring transformers to be taken offline for detailed examination.

The mid-20th century saw the introduction of DGA (Dissolved Gas Analysis) as a powerful diagnostic

of potential issues and proactive maintenance strategies.

With the advent of telecommunications and computing technologies (late 20th century), remote monitoring systems for liquid-filled transformers emerged. These systems allowed for real-time

Current State

Early fault detection via multi-gas monitoring systems allows for the simultaneous measurement of multiple gases dissolved in the transformer oil, such as methane, ethane, ethylene, acetylene, hydrogen,

intervention, preventing potential failures, minimizing downtime, and extending the life of the transformer.

Many recently manufactured transformers implement advanced sensors within the transformer to provide real-time data on parameters

access transformers' data regardless of location. This facilitates timely decision-making and allows for predictive maintenance strategies to be implemented. Integration with asset management systems provides a holistic view of transformer health, maintenance history, and operational data. This comprehensive approach enables informed decision-making regarding maintenance schedules and resource allocation. By combining data from various monitoring technologies and employing predictive maintenance strategies, maintenance activities can be scheduled based on the actual condition of the transformer and supplement predefined intervals when required. This optimizes maintenance efforts while maximizing reliability.

Predictive maintenance assisted by AI (artificial intelligence) algorithms can analyze large volumes of data collected from sensors to identify patterns indicative of impending failures or abnormalities in transformer behavior. By predicting potential issues before they occur, AI enables proactive maintenance interventions, minimizing downtime and reducing the risk of catastrophic failures. AI-powered diagnostic systems can automatically detect and diagnose faults within transformers by analyzing data from various sources, such as dissolved gas analysis (DGA), temperature sensors, and load measurements. This automated process accelerates fault identification, allowing for corrective actions to be taken.

What's Next

The future of monitoring and diagnostic technology for liquid-filled transformers is poised for further advancements driven by emerging technologies, evolving industry needs, and the growing complexity of power distribution networks. Future monitoring systems for liquid-filled transformers will likely incorporate more advanced sensors capable of measuring a wider range of parameters with higher accuracy and precision. These sensors may include advanced optical sensors, acoustic sensors, nanotechnology-based sensors, and IoT-enabled devices,

industry demands for improved reliability and efficiency. In the early days, (late-19th century) of transformers, monitoring, and diagnostic practices primarily relied on visual inspections of transformer components such as bushings, windings, and insulation materials.

tool for assessing the condition of transformer insulation. DGA involves analyzing gases dissolved in transformer oil to detect and identify incipient faults such as overheating, arcing, and partial discharges. This technique revolutionized transformer diagnostics, enabling early detection

monitoring of transformer parameters such as temperature, oil level, moisture, and gas concentrations from a central control center. Remote monitoring systems improved the efficiency of maintenance activities and facilitated potentially faster response to abnormal operating conditions.

and carbon monoxide. As noted, DGA is a widely used method for detecting incipient faults within transformers. Increases in gas concentrations can indicate various faults, including overheating, insulation degradation, partial discharges, and arcing. Early detection of these faults enables timely

such as temperature, oil level, pressure, and gas concentrations. These sensors can be integrated with Internet of Things (IoT) platforms for remote monitoring.

Leveraging remote monitoring capabilities enables operators to

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providing comprehensive insights into transformer health and performance.

Data analytics and AI will continue to play a crucial role in transformer monitoring and diagnostics. Advanced AI algorithms will be deployed to

analyze vast amounts of sensor data, identifying patterns, anomalies, and trends indicative of potential faults or abnormalities. Predictive analytics techniques will enable proactive maintenance strategies, further improving reliability and reducing downtime.

The future of transformer maintenance will shift towards predictive and condition-based monitoring approaches. Predictive maintenance models will leverage AI and machine learning algorithms to forecast potential failures and

prescribe preventive measures based on real-time data and historical trends. Condition-based monitoring systems will enable continuous assessment of transformer health, allowing for timely intervention and optimization of maintenance schedules.

Remote monitoring and control capabilities will be further enhanced, enabling operators to access and manage transformers from anywhere in the world remotely. Advanced communication technologies like 5G and satellite connectivity will

facilitate real-time data transmission and remote diagnostics, improving operational efficiency and responsiveness.

Emerging technologies such as quantum computing, advanced materials, and even robotics may also influence the future of transformer monitoring and diagnostics. Quantum computing algorithms could revolutionize data analysis and optimization tasks, while advanced materials may lead to more durable and reliable transformer components. Drones may be employed to inspect transformers in challenging environments remotely.

The AI Reality

AI technology, specifically Generative AI with Large Language Models (LLMs), has grown exponentially and can potentially provide significant benefits to society. However, these generative tools have yet to be fully integrated into all areas of transformer monitoring and diagnostics. This presents an opportunity for Reliability Engineers, Electrical Subject Matter Experts, and Asset Managers to enhance their transformer diagnostic training and substantially increase their knowledge to support their transformer reliability philosophy. By leveraging Generative AI, they can gain a deeper understanding of transformer monitoring and diagnostics and improve their reliability programs. It's essential to invest the effort now with the available technology to reap the benefits in the long run.

Overall, the evolution of monitoring and diagnostic technology for liquid-filled transformers has been characterized by advancements in sensor technology, data analytics, and limited artificial intelligence. These advancements have significantly improved the reliability, efficiency, and safety of liquid-filled transformers in power distribution networks. The exact when and how of the emerging technologies is yet to be determined. What is known is that the evolution will continue, and so will the need for a resilient electric power system.



PREDICTIVE MAINTENANCE ASSISTED BY AI (ARTIFICIAL INTELLIGENCE) ALGORITHMS CAN ANALYZE LARGE VOLUMES OF DATA COLLECTED FROM SENSORS TO IDENTIFY PATTERNS INDICATIVE OF IMPENDING FAILURES OR ABNORMALITIES IN TRANSFORMER BEHAVIOR. BY PREDICTING POTENTIAL ISSUES BEFORE THEY OCCUR, AI ENABLES PROACTIVE MAINTENANCE INTERVENTIONS, MINIMIZING DOWNTIME AND REDUCING THE RISK OF CATASTROPHIC FAILURES.