GRID STRAIN: HOW AI IS RESHAPING GRID RELIABILITY

INTRODUCTION

The Growing Strain on the Grid

The **U.S. Department of Energy projects AI demand will double or triple by 2028**. Yet much of the grid remains decades old, designed for slower, more predictable growth.

At the same time, utilities are navigating transformer shortages, supply chain disruptions, and retiring field experts, all while trying to modernize systems under mounting pressure.

What happens when exponential energy demand collides with aging infrastructure and unpredictable load?

This eBook explores the many ways AI is impacting grid reliability—and the proactive steps utilities can take to get ahead. From condition monitoring and predictive diagnostics to workforce strategy and infrastructure modernization, it sheds light on how utilities can protect critical assets, prevent failures, and plan smarter for the energy landscape ahead. Because staying resilient in the age of AI isn't just about adding capacity, it's about making better decisions, faster, with the right tools and people in place.

Part 1: The AI Energy Crunch: How Data Centers Are Reshaping Grid Reliability

Artificial intelligence is fueling a quiet crisis for the power grid.

Once confined to labs and startups, AI is now embedded in nearly every sector, from manufacturing and finance to defense. And as adoption grows, so does pressure on the energy infrastructure. Generative AI models and large-scale machine learning systems consume staggering amounts of electricity.

And the grid wasn't built for it. This surge isn't a short-term anomaly; it signals a fundamental shift in energy consumption patterns, both in scale and distribution.

Why AI Demand Breaks the Model

AI doesn't behave like traditional load. It doesn't follow seasonal patterns or predictable usage curves. Demand can spike overnight: when a new tool launches, a data center expands, or computing infrastructure gets upgraded. These aren't minor bumps. They're massive surges that can strain local systems without warning.

Data centers, once built for more predictable IT loads, are now consuming unprecedented electricity to power generative AI training and inference. In North America, AI-related usage is creating high base loads with fewer off-peak cycles, putting sustained stress on transformers, transmission corridors, and substations. These trends are forcing utilities to reevaluate reliability strategies and address deeper systemic risks, often with infrastructure already around fifty years old.

This demand isn't just centralized. With tools like **Google's Gemini AI models now running directly within their data centers**, energy-intensive workloads are landing in facilities never designed for such computing density. That creates instability in areas where **critical grid components are already decades old.**

And because many utilities lack visibility into when or where this demand will hit, they're often forced into reactive mode, trying to stabilize systems already stretched to the limit.

Tariffs, Trade Policy, and Supply Chain Risk Add Fuel to the Fire

At the same time, external constraints are compounding the challenge. Tariffs, trade shifts, and supply chain bottlenecks are delaying access to transformers, bushings, and substation components needed to support grid expansion.

This isn't just about rising costs. It's about time. Infrastructure upgrades are lagging just as AI demand accelerates, creating a dangerous gap between capacity and consumption.

Part 2: Getting Ahead of the Strain, Before It's Too Late

The question is no longer if AI will strain the grid, but how utilities can adapt before disruptions cascade into widespread failures. U.S. data centers alone could account for **nearly half of all electricity demand growth by the end of the decade.**

Yet most grid infrastructure was built for a slower, more centralized model of consumption, not the decentralized, high-density computing clusters emerging today. This volatility is especially dangerous in areas where transmission capacity is limited and substation equipment is aging fast.

In 2024, a single lightning arrestor failure in Virginia **forced 60 data centers offline to prevent a blackout.** The grid narrowly avoided disaster, but the incident revealed just how little room for error remains.

Four Ways Utilities Can Strengthen the Grid

Here are four strategic moves utilities can make to prepare for the complexity ahead:

01 Redesign Infrastructure Plans for Volatility

Traditional five- and ten-year expansion plans aren't built for today's speed of change. Utilities must adopt scenario-based planning that accounts for load volatility, regulatory delays, and sourcing constraints. Upgrades to transmission and substations must reflect the realities of AI-driven demand, not just population growth curves.

At the same time, utilities can't rely solely on scheduled maintenance. Real-time diagnostics and condition-based strategies, like dissolved gas analysis (DGA) and partial discharge monitoring, allow operators to detect stress early and act with precision.

Transmission Gridlocks and Permitting Delays

It's not just transformers under pressure. AI's demand is straining already congested transmission corridors, many of which are difficult to expand due to regulatory and land use hurdles. Major transmission upgrades face **permitting delays of 7 to 10 years in many regions.** In the meantime, aging infrastructure must handle increased load, exceeding original design tolerances.

Substations and protection systems, including breakers, bushings, arresters, and relays, must manage elevated thermal and mechanical stress—making protection testing and real-time monitoring vital to maintaining safety and reliability.

02 Fortify Supply Chains Against Global Risks

Planning is meaningless if equipment can't be sourced. Global tariffs, trade disputes, and inflation continue to delay critical grid components. **Transformer lead times now stretch up to 60 months.**

Multiple factors are driving this bottleneck: limited domestic manufacturing, surging global demand, and Section 232 tariffs on electrical steel, coupled with shifting trade policies. These have compounded cost uncertainty and procurement delays—just as grid upgrades become more urgent. Meanwhile, many transmission-class transformers are operating beyond their intended lifespans. Deferred maintenance, aging insulation, and rising base loads are accelerating wear.

To reduce exposure, utilities must build redundancy into their supplier networks, pursue regional partnerships, and engage regulators to expedite permitting when global pressures threaten project timelines.

03 Build a Future-Ready Workforce

Grid reliability depends on the people behind it. Up to **400,000 U.S. energy sector employees are expected to retire within the next decade**, creating a massive experience gap. Utilities must prioritize upskilling field teams, partner with technical schools and universities, launch mentorship and knowledge transfer programs, and focus on AI-diagnostic training. Without a workforce ready to interpret and act on asset health data, even the best technology can fall short.

04 Move from Planning to Action

Resilience requires more than roadmaps. Utilities must embed agility into their operations by conducting regular failure analysis reviews, applying lessons learned from near-misses, and ensuring field teams can respond to real-time risk signals.

Part 3: AI vs. AI: Can Artificial Intelligence Solve the Grid Strain It's Creating?

AI may be stressing the grid, but it could also help save it.

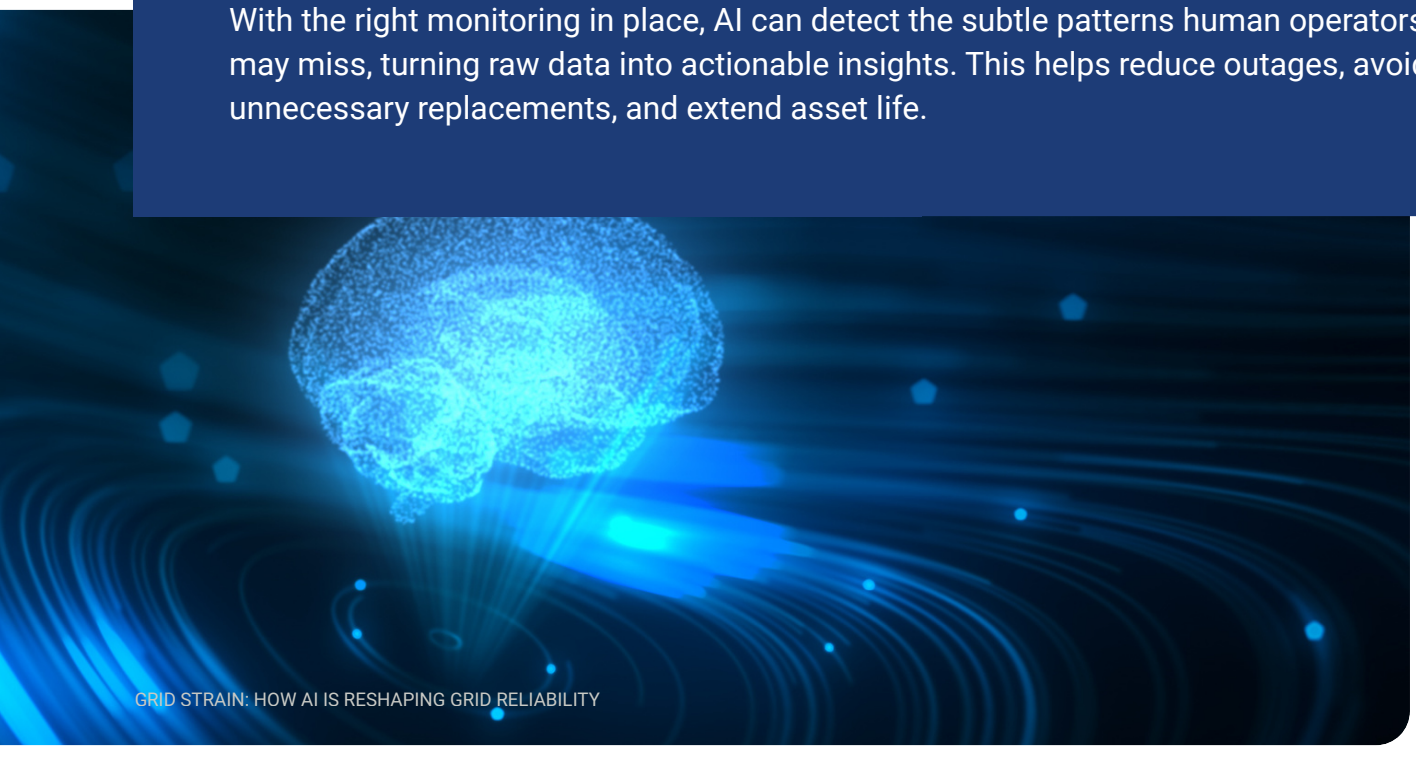
Utilities are already navigating the challenge of rising AI-related load. Now, many are exploring how AI can be part of the solution. From optimizing maintenance schedules to analyzing fleet-wide risk, artificial intelligence—when grounded in high-quality data—is emerging as a critical tool in the grid resilience toolkit.

Predictive Maintenance Powered by AI

One of the clearest and most immediate use cases for AI in the power sector is predictive maintenance.

Unlike traditional time-based models, predictive diagnostics use AI algorithms to flag issues early, well before failure. By analyzing trends in dissolved gas levels, insulation aging, moisture intrusion, and bushing performance, utilities can identify which assets are under stress and take targeted, preemptive action.

With the right monitoring in place, AI can detect the subtle patterns human operators may miss, turning raw data into actionable insights. This helps reduce outages, avoid unnecessary replacements, and extend asset life.



Visibility Is the Prerequisite

AI is only as good as the data it learns from. For AI to inform grid operations, it needs continuous, real-time visibility into asset health. That's where condition monitoring tools come in.

Solutions like Doble's **Calisto™ DGA monitors** and **doblePRIME IDD™ bushing** and **partial discharge** monitors provide the baseline asset intelligence AI needs to make smart decisions. These diagnostics are the bridge between field data and the predictive capabilities of machine learning.

When paired with **asset analytics platforms**, utilities can unlock system-wide insights, track degradation trends, and automate risk alerts across their fleets.

Smart Protection Requires Smarter Testing

AI may help optimize operations, but when faults occur, protection systems still need to respond instantly and correctly. That means rigorous testing is essential to ensure foundational systems perform under stress.

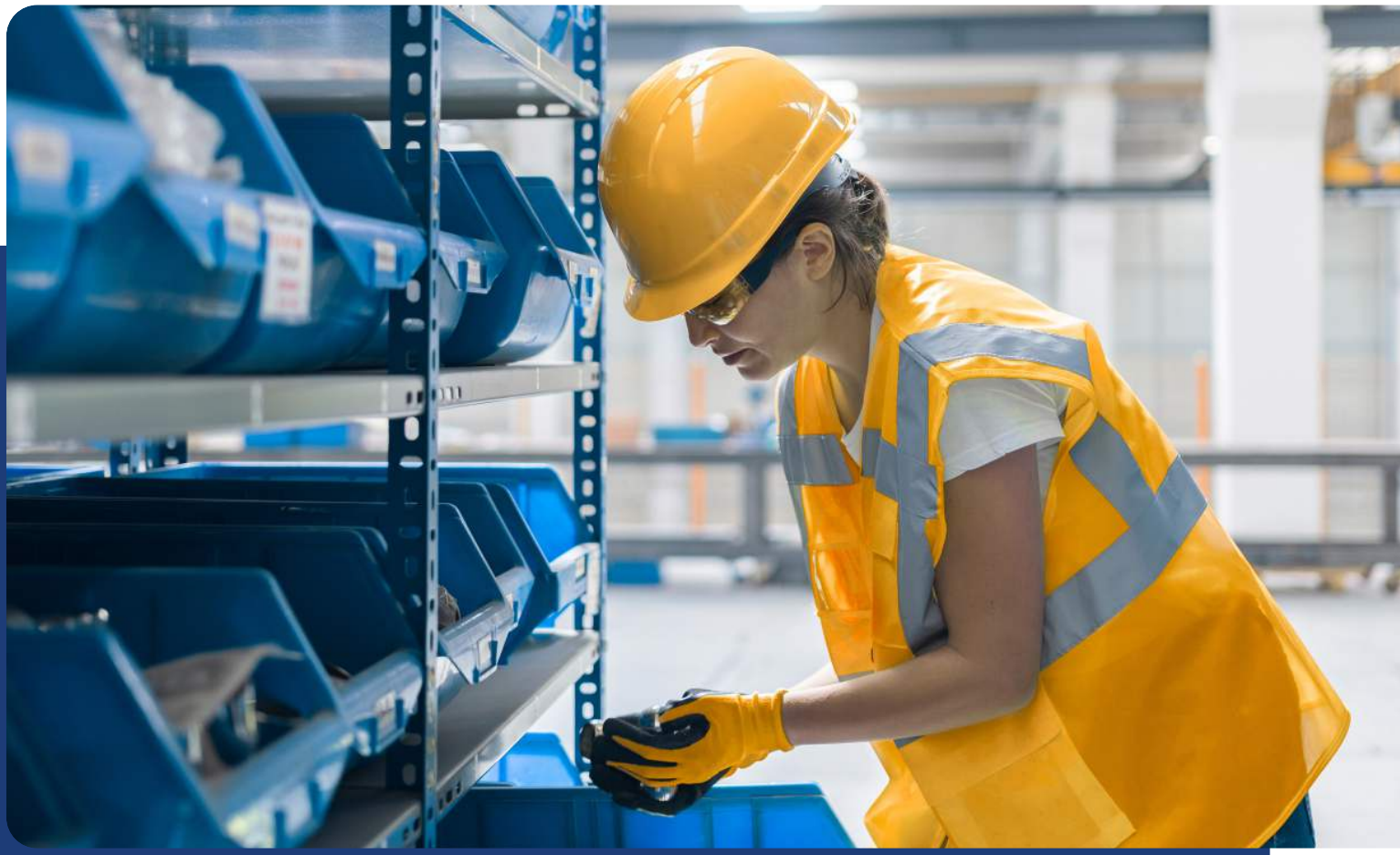
Tools like the **F6150sv™ relay test set** and **Protection Suite™** software allow utilities to simulate real-world events, validate relay settings, and test logic schemes to ensure every layer of grid defense functions as expected. These tools support a smarter, self-healing grid where even advanced AI systems are backed by proven engineering protection.

People + AI: A Hybrid Reliability Model

AI doesn't replace utility expertise, it enhances it. While machine learning models can process vast quantities of sensor data, field crews and engineers remain essential in interpreting results, refining strategies, and executing complex fixes.

That's why utilities are combining AI tools with workforce development initiatives. Diagnostic training, scenario simulations, and mentorship programs help ensure that human judgment stays central to grid decision-making.

A hybrid approach, pairing predictive intelligence with human experience, offers the most powerful model for navigating the next era of grid reliability.



Part 4: Reactive to Predictive: Why AI-Powered Condition Monitoring Matters More Than Ever

Artificial intelligence is **driving exponential energy demand** and exposing just how fragile many grid systems really are. In response, utilities are rethinking not just how they plan infrastructure, but how they maintain it.

As transformer shortages, aging infrastructure, and unpredictable, always-on energy use converge, utilities across North America are adopting AI-powered condition monitoring and predictive diagnostics to detect risks earlier, act faster, and protect more with fewer resources.

It's a shift from reactive response to intelligent prevention. And for many, it's already paying off.

From Time-Based Maintenance to Predictive Action

Historically, utilities operated on fixed timelines: testing equipment every few years, replacing components after a set number of hours. But as demand outpaces capacity, this model is no longer viable.

AI-enhanced diagnostics allow utilities to assess failure risk with greater precision by processing both historical performance data and live condition inputs. By surfacing early indicators of equipment stress, these tools enable more timely, targeted interventions before issues become visible through traditional methods.

This isn't hypothetical. Utilities are already seeing results. Many are avoiding unnecessary replacements, reducing outages, and improving their ability to prioritize interventions.

Smarter Tools, Smarter Decisions

Predictive AI only works with a strong data foundation. That's where condition monitoring comes in.

Solutions like the previously mentioned Calisto™ DGA monitors and doblePRIME™ bushing and partial discharge monitors, deliver the real-time insight AI needs to analyze asset health. Paired with **asset analytics platforms**, these tools help utilities automate alerts, track fleet-level trends, and build models that guide smarter decisions.

By shifting from static testing to continuous monitoring, utilities gain:

- Earlier detection of emerging risks
- More targeted maintenance and inspection schedules
- Reduced downtime and maintenance costs
- Extended asset life—especially for transformer fleets under stress

Preparing for What's Next

AI-based condition monitoring is no longer a future vision. It's a present-day strategy helping utilities stretch resources, reduce downtime, and prevent instability before it starts.

But diagnostics alone aren't enough. Utilities must pair smart monitoring with long-overdue infrastructure upgrades. The path forward is clear:

- Use diagnostics to target capital investment
- Extend asset life through condition-based maintenance
- Leverage data to manage transformer shortages
- Improve substation and transmission protection to avoid cascading faults

AI's energy growth is inevitable. The grid's limitations don't have to be. Transformer shortages, permitting backlogs, and asset degradation won't disappear overnight. But with smart planning, utilities can manage risk, shore up reliability, and invest where it counts.

At Doble, we're helping utilities strengthen their infrastructure by harnessing AI while grounding it in expert diagnostics, fleet-wide insight, and proven engineering support so they can make better decisions, faster—because the future of AI-powered energy depends on what we do today.

Ready to build a more resilient, AI-ready grid?

Let's talk about how Doble can help you harness AI-powered condition monitoring and proven diagnostic tools to protect critical assets, prevent failures, and make smarter investment decisions.

Explore Doble's solutions for condition monitoring and predictive maintenance here.

ABOUT DOBLE ENGINEERING

Doble is the world's most trusted brand in electrical diagnostics. We provide energy system engineers with the tools, insights and confidence to anticipate and overcome tomorrow's power demands today.

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