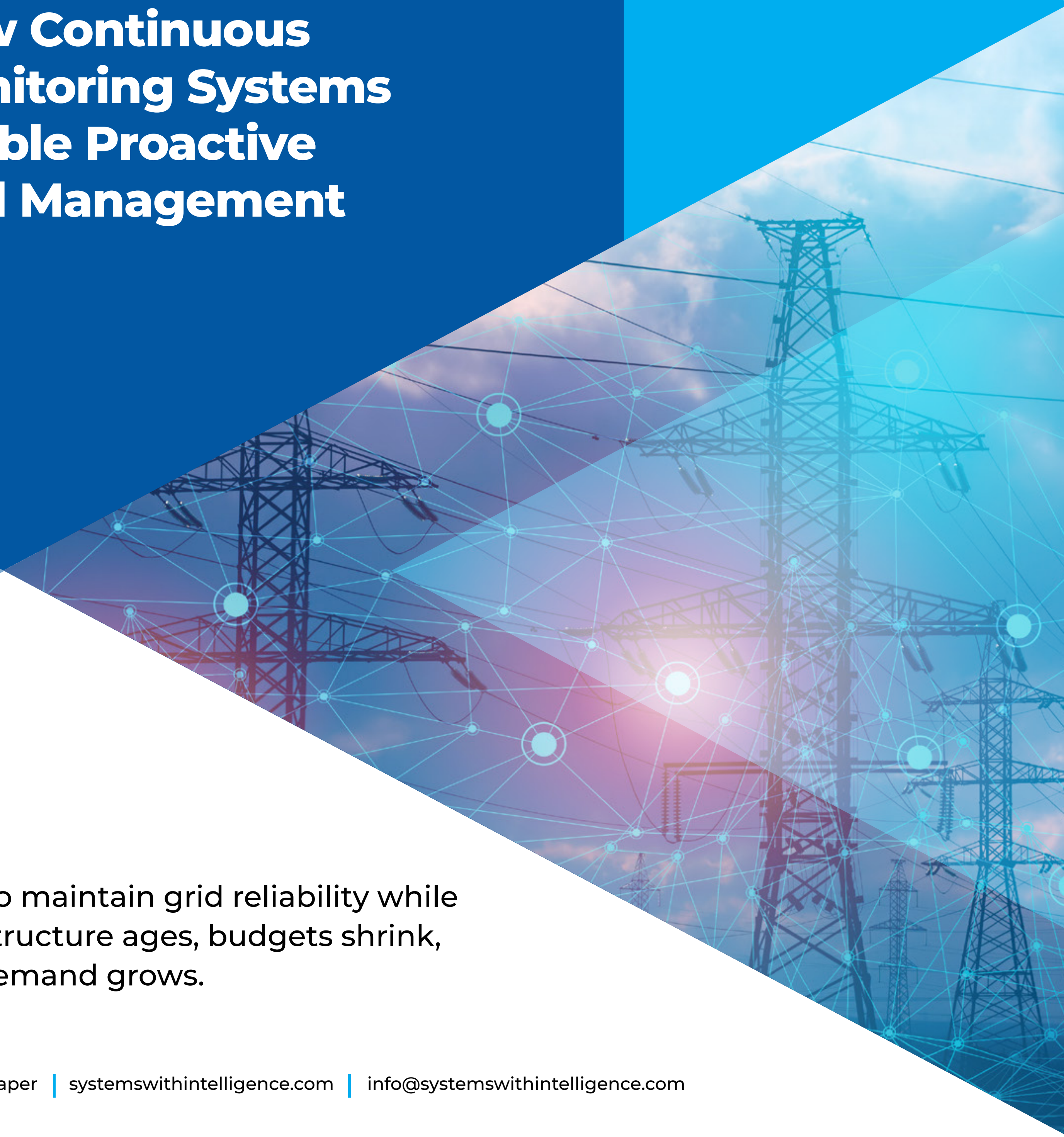
Beyond Manual Inspections:

How Continuous Monitoring Systems Enable Proactive Grid Management



How to maintain grid reliability while infrastructure ages, budgets shrink, and demand grows.

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Utility executives are facing a significant challenge: how to maintain grid reliability while infrastructure ages, budgets become tighter, and demand grows. The traditional approach—annual thermal inspections and reactive maintenance—is quickly proving inadequate as critical assets reach end-of-life and stress on the system intensifies.

Yet major utilities are demonstrating there's an alternative, a proven way to meet infrastructure issues head-on. By implementing continuous monitoring, technology that's available today, they're seeing significant cost savings, improved reliability, and longer asset life. (Not to mention reduced operational risks.)

These aren't theoretical benefits. They're measurable results from SWI customers that are already operating thousands of monitored substations.

A Perfect Storm for Utilities

North American utilities are facing an unprecedented convergence of challenges, and traditional maintenance approaches are struggling to keep up.

The average age of the installed base is forty years old, with more than a quarter of the grid older than half a century. Yet even as this infrastructure continues to age, demand is growing at never-before-seen levels. Recently published numbers from the EIA predict that power demand will rise to 4,193 billion kWh in 2025 and 4,283 billion kWh in 2026. That's up from 4,097 billion kWh in 2024, which was itself a record.

The transformer fleet presents particularly acute challenges. A 2020 study by the U.S. Department of Commerce found that the average age of in-service large power transformers is 38 years. For the most part, that's near or past their design life.

Yet, to maintain the status quo by upgrading this existing infrastructure would require investing more than $700 billion. What's more, if utilities also account for the anticipated growth in demand that electric vehicle adoption will bring—potentially a 45 percent increase—this required capital investment could exceed a trillion dollars by 2050.

Numbers like those are simply untenable.

Meanwhile, reliability can only be said to be suffering. For evidence, look to the U.S. distribution system, where the average SAIDI value increased (even when excluding major event days) from 106.1 minutes per customer in 2013 to 125.7 minutes in 2022.

On top of these infrastructure challenges, utilities are also facing a workforce crisis. Energy Central, for example, reports that more than a third of gas and electricity sector employees are likely to retire in the next decade. That translates, according to industry surveys, to more than 70,000 replacement lineworkers, technicians, plant operators, and engineers needed nationwide. Never mind the staffing challenge; as decades of expertise walk out the door, the impact on grid reliability can't be reckoned with.

The economic impacts of these stresses on the system compound quickly and cascade into customer satisfaction issues. The U.S. Department of Energy estimates power outages cost American businesses around $150 billion a year, and although this number looks staggering, it makes sense when you consider what downtime costs companies. For a large manufacturing enterprise, a single hour-long outage could be $5 million hit; data center outages now cost more than $8,800 per minute.

Why Annual Inspections Can't Keep Up

Traditional thermal inspections take a snapshot in time, usually less than one hour out of 8,760 hours of annual operation.

This is a mismatch for monitoring assets under continuous stress, and may even result in a catastrophic mistake. "Point-in-time" monitoring overlooks the signs of many load-dependent failures, given that they only manifest under high demand or in specific weather conditions. (Think of the transformer bushing that develops heating problems during peak summer load; it may appear normal when inspected in the spring and continue degrading undetected for months.)

Utilities may even end up servicing healthy equipment while they miss developing problems that fall between predetermined inspection intervals; this is just the reality of time-based maintenance schedules.

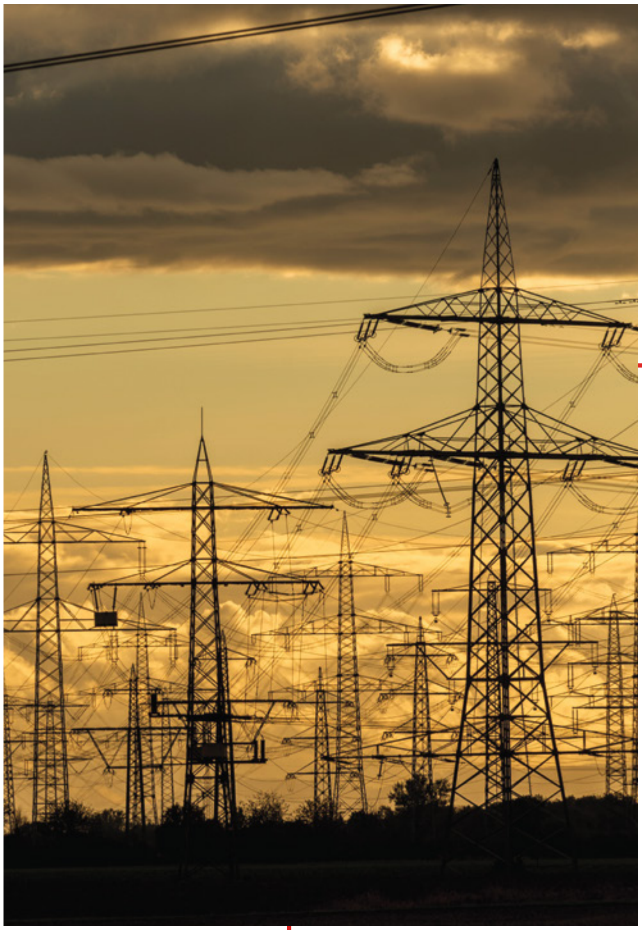
The human factor can also introduce additional limitations. Different thermographers may interpret identical asset conditions differently, meaning that "pass or fail" can come to depend entirely on the individual experience level of the person doing the inspecting.

Further, as experienced personnel retire (as discussed above), utilities will lose the pattern recognition skills that their veteran thermographers have developed over the course of decades. This "brain drain" will make it more and more difficult to distinguish between normal operational variations and early indicators of failure.

However, the larger problem is the cascading effect of equipment failure throughout a highly interconnected system. If a critical transformer fails unexpectedly, utilities must implement emergency load transfers and dispatch emergency repair crews, all while customers experience service disruptions that damage a utility's reputation, torch customer goodwill, and invite regulatory scrutiny.

The inspection gap becomes even more problematic when you consider the realities that utility operations face. Manual inspections require coordinating specialized staff and safety equipment. Outages must be planned, and sometimes even traffic control is needed. These logistical requirements mean that even when imminent problems threaten equipment, inspections or maintenance can be delayed by weeks or months. Meanwhile, those assets continue to operate under the same stress conditions that may accelerate their failure.

The Case for Continuous Monitoring



To meet this increasing pressure, many utilities find themselves evaluating numerous "digital transformation" initiatives.

These typically come with uncertain timelines and even more uncertain benefits. For instance, despite promises of revolutionary changes around the corner, most AI-powered solutions remain in development. For another example, digital twins require years of data collection to provide any real value.

That's why we at SWI suggest that utilities should focus on proven technology that addresses their immediate operational needs, rather than waiting for "perfect" solutions in the future.

Put simply, continuous thermal monitoring technologies more than fit the bill, as they provide several key advantages over traditional inspection methods.

First, these technologies are typically installed non-intrusively, requiring no physical connection to power equipment. This eliminates the safety risks and operational complexity that are almost always associated with direct attachment monitoring.

These systems also meet utility-grade specifications designed specifically for substation environments, including the IEEE 1613 and IEC 61850-3 standards which ensure reliable operation under electromagnetic interference, voltage surges, and extreme temperature conditions.

And since they continuously compare temperature readings against established baselines, they can provide immediate alerts when conditions exceed preset thresholds. SCADA integration (using standard utility protocols like DNP3 and MODBUS) means they can be seamlessly incorporated into existing operational workflows. Additionally, historical data storage makes it easy to analyze trends and enables planning for condition-based maintenance.

Best of all, deployment can scale from individual IoT sensors monitoring specific assets to full substation monitoring systems. This means utilities can start with targeted deployments on critical equipment, then expand coverage based on demonstrated value.

But what does continuous monitoring enable that time-based inspections simply can't? To put it simply: continuous visibility, greater confidence, and immediate insight.

What Continuous Monitoring Offers

What if you could get 24/7 asset visibility, correlated with actual operating conditions, including load, weather, and system stress? Continuous monitoring helps you see asset degradation patterns that are invisible during periodic inspections and get immediate alerts so you can respond quickly when conditions show that problems are developing.

You'd also feel more confident that maintenance work actually resolved any problems you did find. Normally, you'd have to schedule follow-up inspections to verify repairs, but continuous systems provide immediate confirmation when operating temperatures are back to normal. Translation: you'll sleep easier knowing everything is OK, instead of simply hoping so.

Another critical benefit is remote awareness. When disturbances happen, operators can immediately make assessments *without* dispatching inspection crews, enabling faster and more informed decision-making.

Beyond these advantages, continuous monitoring provides a quality and consistency of data that manual inspections can't match. Every measurement is taken from the exact same position, using accurate, precision-calibrated sensors. This consistency may seem like overkill, but it's vitally important; it's what enables trend analysis across weeks, months, and years.

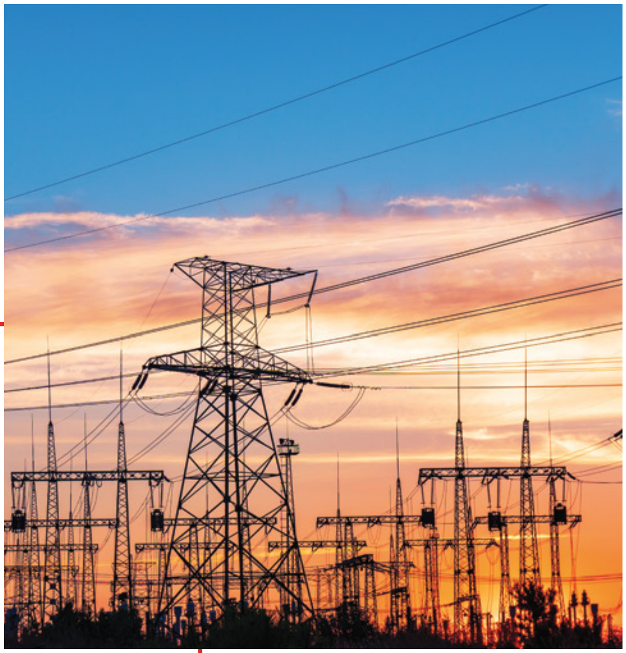
It's also much easier to correlate variations in temperature with changes in load, shifting weather conditions, and operational events, all in real-time. Unlike point-in-time inspections, continuous monitoring easily reveals patterns that help operators distinguish between operational variations and developing problems, meaning more "saves" and healthier equipment.

Southern Company: Continuous Monitoring in Action

The second-largest utility in the United States, Southern Company, had a specific objective in mind: to extend on-site transformer inspection cycles by at least 200%. While they had already deployed online Dissolved Gas Analysis and bushing monitoring, a critical gap still remained. No continuous infrared monitoring was being done.

When SWI got involved, Southern Company made it clear that any solution needed to meet multiple criteria:

- Be simple enough to install that a two-person team could set it up on multiple transformers in a single day without an outage.
- Monitor all the critical points they identified on a typical transformer.
- Stand up to Category 2 hurricane winds while maintaining wireless communications and low power consumption, since weather in the service territory was often severe.
- Keep the sensor, cloud dashboard, and data storage secure and isolated from the Southern Company network and pass a comprehensive third-party vendor risk assessment before installation.
- Integrate with the OSIsoft PI system so it could interface with Southern Company's asset management, operations, and maintenance applications.



Enter SWI's IM500

Systems With Intelligence worked closely with Southern Company to develop a specialized IM500 mounting system that attached directly to transformer bodies using industrial-strength magnets rated for power transformer operating temperatures.

The system used high-strength fiberglass construction with adjustable clamps, thus enabling optimal positioning and rapid installation.

IM500 sensors are engineered to operate reliably in conditions that would challenge consumer-grade electronics, featuring robust protection against electromagnetic interference (EMI), electrostatic discharge (ESD), and voltage surges and interrupts. For Southern Company, they were pre-programmed to monitor critical transformer subsystems, including bushings, lightning arresters, load tap changers, cooling systems, and main tank connections.

And while the utility's service area didn't demand this level of robustness, it's helpful to know that the IM500 is immune to electromagnetic interference up to 10 V/m (compliant with IEEE 1613) and rated for operation in a temperature range of -15°C to +70°C (with storage from -40°C to +85°C), making it suitable for most industrial and utility applications. An IP67-rated enclosure further ensures resilience in difficult outdoor environments.

IM500s were used to cover all of the transformer's critical points, including the arrestors, bushings and connections, load tap changer components, main tank surfaces, and radiator inlet and outlet connections.

Thermal data collection, storage, and analysis happened continuously, with connections to the SWI Cloud authenticated and encrypted for data security. A comprehensive dashboard provided temperature trending graphs, along with visual and thermal images; automated email alerts notified operators and maintenance experts when temperatures exceeded preset thresholds.

Nominal power consumption was approximately 1W per device, though the power supply was sized to deliver at least 5W for reliable operation. This allowed the IM500 to run from existing auxiliary power supplies, minimizing the need for additional infrastructure. (If necessary, optional solar-powered junction boxes were also available to make the IM500 completely independent from utility power sources.)

Documented Saves

The deployment resulted in multiple pieces of equipment being identified as ready to fail before any catastrophic failure actually occurred.

These saves across various transformer systems included overheating bushings, failing lightning arresters, load tap changer problems, cooling system malfunctions, and connection point heating.

The SWI continuous monitoring system detected these developing problems during normal operations, enabling *planned* repairs instead of emergency responses.

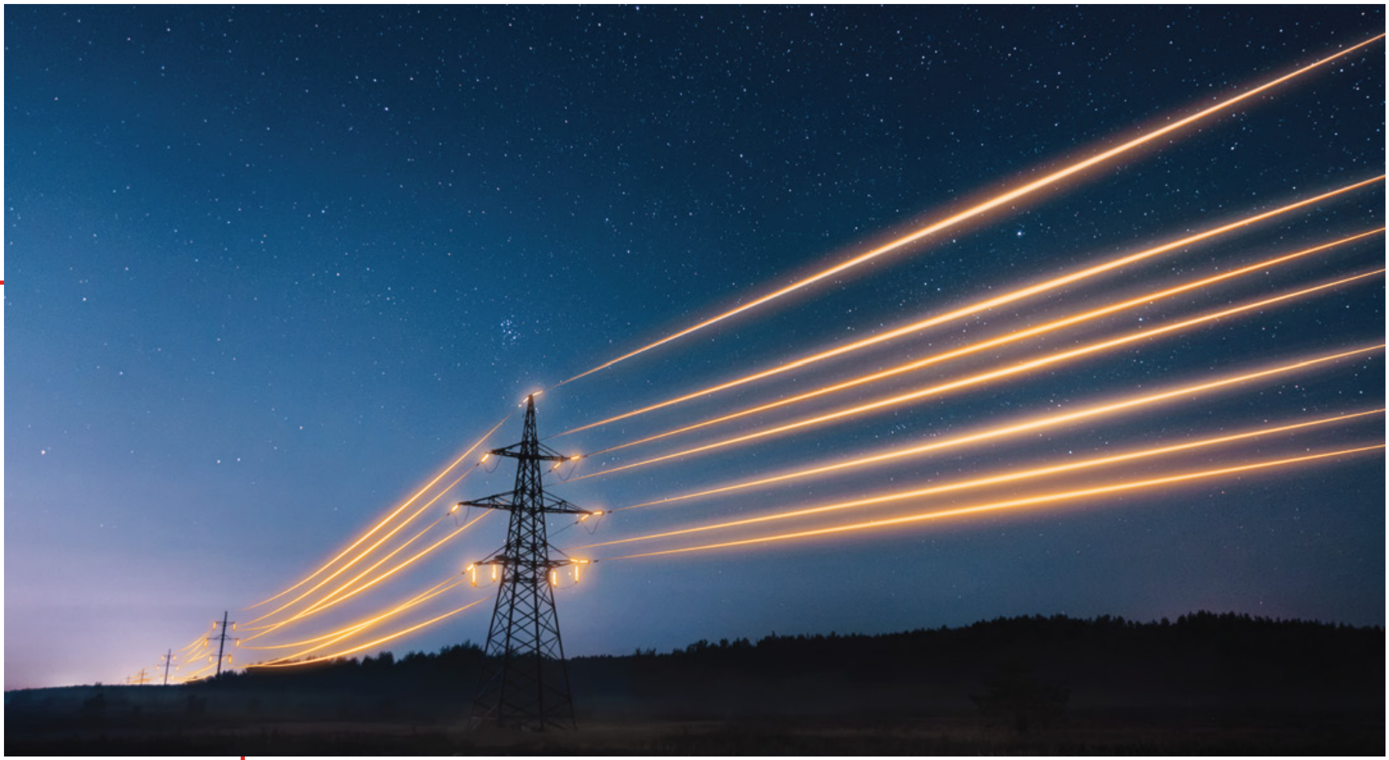
The result? By preventing equipment damage, avoiding outages, and eliminating emergency response expenses, the IM500 deployment delivered significant cost savings (in the six and seven figures per incident).

It's also fair to say that this continuous monitoring implementation delivered benefits far beyond Southern Company's original goal. Real-time detection provided unexpected operational value, and it became remarkably easy to confirm when repairs successfully restored normal operating conditions. The confidence that this knowledge gave transformed Southern Company's approach to managing its transformer assets.

Improvements in data quality proved equally valuable for Southern Company's engineering teams. Instead of snapshot measurements taken during specific weather and load conditions, engineers now had access to comprehensive temperature profiles showing how their equipment performed across different seasons, through varying load cycles, and in weather events.

Southern Company's success shows what's possible when proven technology is deployed with clear goals and proper planning.

But how can other utilities replicate this success? The answer lies in a phased approach that starts small and scales.



Intelligent Monitoring is Still the Goal, But in the Meantime...

Implementing continuous monitoring today builds the foundation for more sophisticated monitoring tomorrow. At SWI, a "crawl, walk, run" methodology is used to offer a practical way to explore new technologies while still enjoying immediate value.

Crawl: Implement Proven Technology Like Thermal Monitoring

In the "crawl" phase, deploy continuous thermal monitoring on critical assets and document the savings and operational improvements. This foundation will build organizational confidence in monitoring technology. It should also give you the kind of immediate return on investment that Southern Company experienced.

The first step is choosing the right assets to monitor. You'll want to focus on high-value, high-risk equipment where monitoring can make the biggest difference. Think transmission transformers, critical distribution substations, or equipment that's had problems before.

Integration is also important; getting it right from day one will matter more than you might think. The utilities that see the best results connect thermal monitoring data directly to their existing SCADA systems so operators can see everything in one place. This way, monitoring becomes part of normal operations instead of a separate workflow.

You'll also want to track the right metrics to prove the value of continuous monitoring and more easily justify expanding the program when it's time to move to the next step. Keep a list of equipment saves like Southern Company did, track reduced inspection costs, demonstrate that you're planning for maintenance better, and, if you can, show how regulatory compliance has improved. These wins will become your business case.

Walk: Add Visual Analytics

Visual analytics can spot problems that thermal monitoring misses, so it's a logical next step in implementing next-generation equipment. Computer vision systems can detect structural issues, corrosion patterns, oil stains, equipment that's shifted position, and even vegetation growing too close to equipment.

In the "walk" phase, then, you'll enhance your continuous thermal monitoring with visual inspection. This will help you build comprehensive libraries of asset condition examples, which in turn will allow you to analyze equipment condition trends in a more sophisticated way. Advanced systems can even compare current images with historical ones to automatically spot new damage.

To make visual inspection work, however, you'll need to build up libraries of what different problems look like, since machine learning gets better at detection as it processes more data. For transformers, for example, that means teaching your system to recognize things like oil leak patterns around bushings and cooling systems, rust on tank surfaces, or structural problems with mounting systems. Or for switchgear, visual analytics can discover contact wear, cracked insulators, and things like arc damage that might not show up as heat problems right away.

The real power in the walk phase comes from combining your thermal and visual data. Thermal monitoring will catch active problems that are generating heat, while visual analytics will spot structural issues that could become thermal problems later. Put them together, and you've got a truly predictive maintenance strategy.

Run: Move to Comprehensive Asset Intelligence (When Available)

The goal of the final "run" phase is to correlate data across multiple asset types and locations. Robust predictive analytics will help you optimize maintenance and build toward a comprehensive view of asset performance.

This is where things get really interesting, but also where we move into "someday" territory. Eventually, utilities will enjoy asset intelligence that combines thermal monitoring, visual analytics, electrical measurements, environmental sensors, and operational data to build a complete picture of how your equipment is performing.

The ultimate goal is a digital twin model of your physical assets that updates in real-time based on monitoring data. You'd be able to run "what-if" scenarios and optimize maintenance schedules around the way different pieces of equipment interact.

When they're "ready for prime time," these advanced implementation tools will enable fleet-wide health monitoring and inform strategic decisions about assets.

Instead of just monitoring individual pieces of equipment, you'll be able to compare asset performance across your entire system. You might discover, for example, that a particular transformer design *always* develops bushing problems after fifteen years; this kind of knowledge will let you plan proactive replacements before failures happen.

However, that's a big "when." Since no one can predict when these kinds of tools will be widely available, we feel it makes the most sense to start with proven tech that sets you up for more advanced implementations at a later date.

The smart approach? Start building your foundation now with proven monitoring technology. The thermal and visual data you collect during the crawl and walk phases will become the baseline you'll need when future tech "comes online."

The Choice is Clear

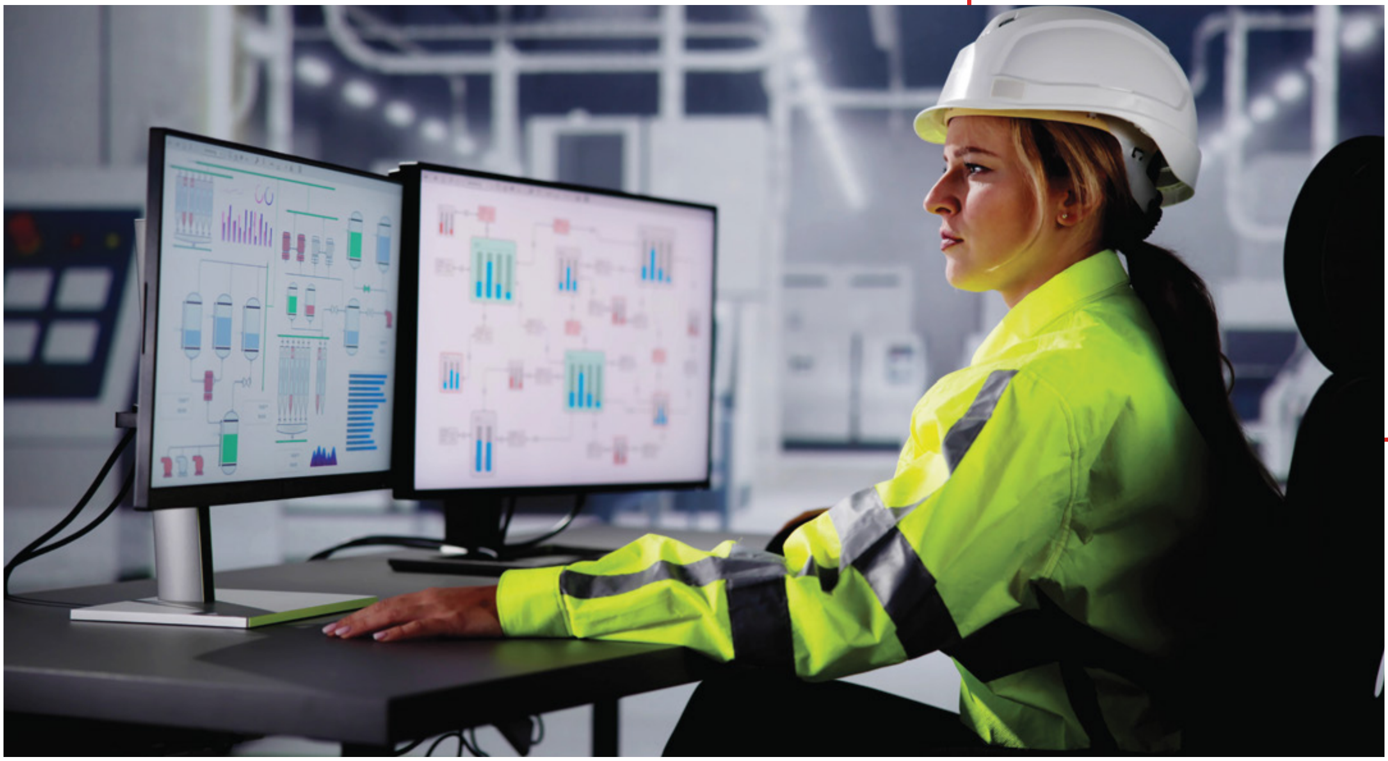
You don't have to choose between aging infrastructure and unaffordable replacement costs. Continuous monitoring technology that's available today can help extend asset life, reduce maintenance costs, and improve reliability.

Major utilities working with SWI have seen significant returns on investment using Touchless™ Monitoring solutions by avoiding equipment failures and optimizing maintenance strategies. Touchless™ Monitoring leverages visual & thermal sensors to enable continuous, 24/7 monitoring of high-value and critical substation assets. With greater situational awareness, utilities can quickly detect faults, diagnose causes, and prioritize repairs based on the overall health and performance of the asset.

Our track record of 140+ utility customers monitoring 2000+ substations demonstrates that Touchless™ Monitoring is the new operational standard—and that it certainly makes sense to implement it on the path to even more intelligent technology.

The wins and saves provided by continuous monitoring also demonstrate to key customers—especially industrial customers and large loads—that proactive measures are being taken to keep key utility equipment in good shape as it ages. By showing they're aiming for (and achieving) reliability goals, utilities can improve customer satisfaction and demonstrate they're avoiding costly downtime.

To sum up, there's no question that continuous monitoring works; documented results from Southern Company and others prove its effectiveness. The real question is, with predictive maintenance programs typically reducing maintenance costs by up to 30% and extending equipment life by 20-40%, how long can you continue with the status quo?



About Systems With Intelligence

Systems With Intelligence (SWI) is the trusted global leader in Touchless™ Monitoring solutions for electric utilities and industrial applications. Founded over 15 years ago, SWI pioneered real-time thermal imaging for substations and has deployed thousands of monitoring systems worldwide. The company's sensor networks and analytics platforms enable utilities to achieve dramatic O&M savings while building the data foundation for grid modernization and autonomous operations.