

Designing Substations for Safety and Maintainability

by **Mark Paul**

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INTEGRATING INSPECTION ACCESS FROM DAY ONE

Modern substations are evolving. Once seen purely as physical nodes for power transformation and distribution, they are now considered strategic assets, as centers of operational safety, compliance assurance, and long-term equipment health. As demands on reliability, uptime, and sustainability intensify, the expectations placed on substation infrastructure have changed dramatically. Gone are the days when systems were designed solely for capacity and protection. Today, a substation must support seamless maintenance, real-time inspection, and zero-compromise safety from the very beginning.

Yet, in the design process, one critical factor often remains overlooked: inspection access.

Across utilities and industrial sites alike, operators are under increasing pressure to maintain aging infrastructure while meeting ever-tightening regulatory standards. The shift toward condition-based maintenance, the rise in arc flash safety awareness, and workforce constraints due to skilled labor shortages all contribute to the urgency of a new approach. Within this landscape, integrating inspection access directly into the substation design—from the earliest stages of engineering—offers a powerful and practical way to future-proof performance, simplify compliance, and protect people and assets.





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Designing for inspection doesn't require radical innovation or budget-busting upgrades. It simply means embedding practical tools into the infrastructure that make routine maintenance safer, faster, and more accurate. That includes built-in thermal imaging access via infrared (IR) windows, acoustic ports for ultrasound inspection, visual temperature indicators like thermochromic labels, and digital tools that verify and track each inspection event. These aren't complex add-ons—they're straightforward, scalable enhancements that transform how substations are serviced across their full lifecycle.

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The benefits of this approach extend far beyond the inspection itself. When inspection tools are built into the design, maintenance teams no longer need to open energized equipment or shut down critical systems to collect data.







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This dramatically reduces the risk of arc flash or electrical shock, keeps equipment in service, and ensures that inspections are conducted under true operating conditions. That, in turn, improves the accuracy of thermographic scans and acoustic readings, providing earlier warning of failures and more actionable insights.

Designing substations with access in mind removes the common excuse for missed inspections: it's too risky, too disruptive, or too expensive. If thermal and acoustic ports are already in place, inspections can be completed in minutes by qualified technicians without downtime. That shift—from deferred or emergency maintenance to routine, proactive service—can be the difference between a minor repair and a catastrophic failure. Reliability is no longer left to chance or delayed by bureaucracy.

This approach also delivers significant financial advantages. Retrofitting inspection points after installation is always more expensive than incorporating them during the design and construction phases. When IR windows and ultrasound ports are added as part of the initial layout, the labor, engineering, and coordination costs are minimal. Trying to do the same job five years later—often around live equipment and during tightly scheduled outages—requires far more time, money, and risk mitigation. Additionally, avoiding planned or unplanned shutdowns for inspections saves operators countless hours of lost productivity, especially in high-demand sectors such as manufacturing, healthcare, and data centers.

Regulatory compliance is another area where design-integrated inspection pays dividends. Standards like NFPA 70E and 70B, OSHA requirements, and IEC guidelines all point toward safer, more accountable inspection practices. By making it easy to conduct and document closed-panel inspections, built-in access helps facilities maintain detailed records and demonstrate compliance.

It also aligns with the Hierarchy of Controls, moving organizations away from risky administrative and PPE-based solutions and toward elimination and substitution. Essentially providing safer, more reliable strategies by design.

So what does this actually look like in practice? Consider switchgear, one of the most common substation components with high inspection demand. A well-designed lineup will include IR windows positioned to allow thermal imaging access to busbars, breaker contacts, and cable terminations. It might also incorporate ultrasound ports or sensors that allow a technician to detect partial discharge, such as arcing or tracking, without opening the gear. These ports or sensors can be positioned on doors or covers and offer consistent, repeatable acoustic pathways for condition-based monitoring.

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Similarly, large transformers can benefit from infrared windows strategically placed near high-loss areas like terminal connections or internal tap changers. These windows enable routine scans to detect insulation breakdown or load imbalances long before overheating leads to failure. Adding thermochromic indicators—color-changing labels and clips that react to elevated temperatures—provides a continuous passive warning system that any operator or inspector can see at a glance. By combining active and passive inspection tools, designers give maintenance teams both the detailed data and the everyday visual feedback needed to catch problems early.

In enclosed substations or control buildings, inspection access can be paired with smart layout choices. Designers can avoid placing obstacles between inspection points and panel doors, allow room for thermal camera operation, and position enclosures to allow safe, unobstructed access. Including NFC tags that link to digital inspection records adds another layer of integration—streamlining the connection between the physical infrastructure and the digital asset management system. The result is a site that is not only easier to inspect, but far more likely to stay in compliance over time.

The contrast between retrofitting and designing right from the start couldn't be clearer. A facility that installs gear without built-in access often faces hard choices down the line: risk worker safety by opening energized panels, schedule expensive shutdowns to inspect offline, or pay to retrofit dozens of IR windows and ports under high-stakes conditions. These delays and complications can be avoided entirely by specifying inspection access as part of the equipment procurement or build plan. What's more, original equipment manufacturers increasingly support this model, offering switchgear, transformer, and MCC configurations with access points pre-installed at the factory.

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And this isn't just theory. Facilities that embrace design-integrated inspection report fewer unplanned outages, more accurate asset data, and better alignment with maintenance

schedules and staffing capabilities. In critical power environments—hospitals, water treatment plants, semiconductor factories—the ability to monitor equipment safely and efficiently is no longer a luxury. It's an expectation. Choosing not to design for maintainability is effectively choosing to increase long-term operational risk.

Substations must be designed not just for what they do today, but for how they'll be maintained tomorrow.

This testing is used to provide one. At its core, this shift represents more than just a technical upgrade. It reflects a deeper mindset change: a move from reactive maintenance to reliability engineering, and from short-term construction savings to long-term operational efficiency. Designing substations for inspection access is a simple, scalable, and profoundly practical way to future-proof your infrastructure while protecting your people and your power.

As the utility industry continues to face mounting regulatory scrutiny, aging infrastructure, and changing workforce demographics, designing for safety and maintainability isn't just wise... it's necessary. Whether you're building a new facility or modernizing an existing site, integrating inspection access into your blueprint gives you a critical edge. It improves performance. It simplifies compliance. It protects your workers. And it pays for itself many times over across the life of the asset.

Substations must be designed not just for what they do today, but for how they'll be maintained tomorrow. Embedding inspection access from day one transforms substations from vulnerable points of failure into resilient, reliable assets. It's not just better thinking—it's better engineering.