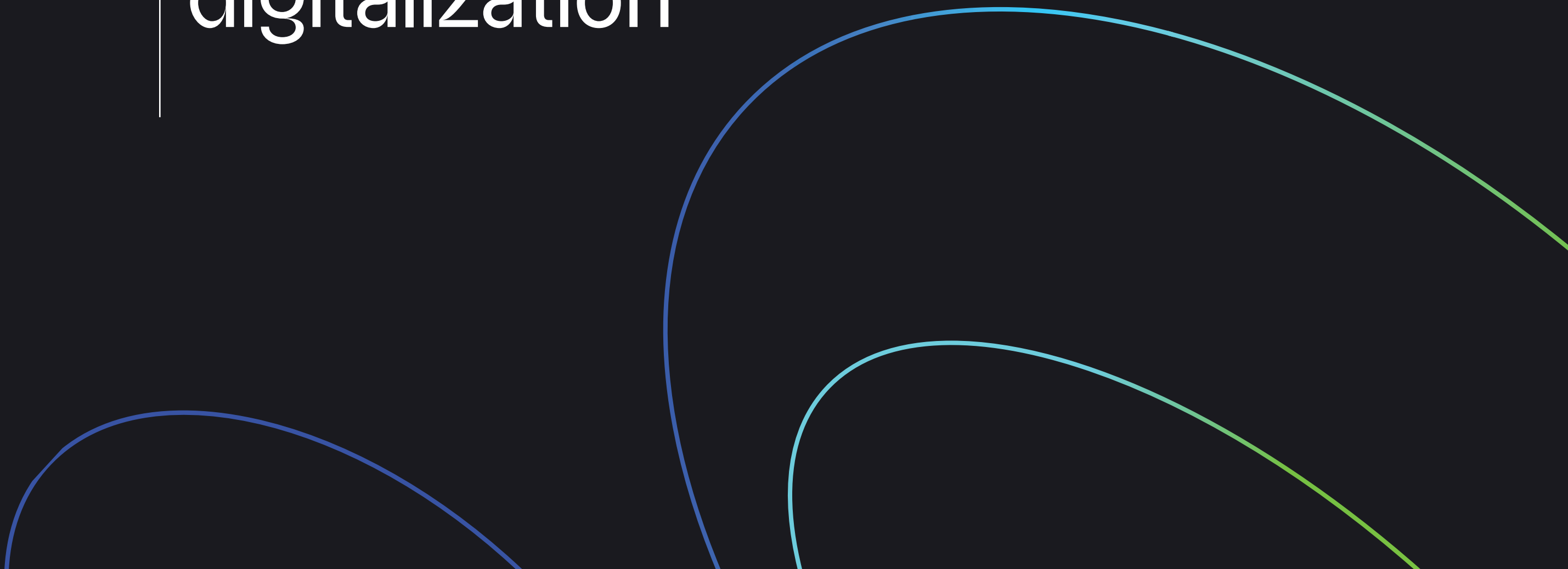




Unplugging power sector challenges through digitalization

EBOOK



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Introduction

The global power industry is at a critical inflection point. It must continue to deliver reliable energy to modern society and industry while meeting a surge in electricity demand driven by electrification and the growth of data centers to support AI.¹ At the same time, affordability and economic viability remain critical. And all of this must happen while reducing environmental impact and addressing climate change.

For decades, the increasingly dynamic sector, spanning generation, transmission, distribution and utilities, has turned to digitalization to achieve operational excellence, enhance efficiency and ensure resilience. Yet, legacy systems, fragmented data and evolving regulations continue to slow momentum. The path forward requires a more integrated approach that connects data and workflows into a digital thread across the entire asset lifecycle.

This ebook explores what it takes to move faster. It highlights why digital integration matters and outlines the strategic priorities that will help power organizations navigate complexity and deliver stronger outcomes.



Encoding the value of digital transformation

While the energy sector's push toward innovative digital technologies dates back to the 1970s, by the early 2010s, power plant automation was already well-advanced. Facilities had moved beyond boiler-turbine generator boards and vertical panels, adopting open systems built on industry-standard hardware and software. Then came a turning point. Around 2012,² the rise of the "industrial internet of things" (IIoT) reshaped the landscape, connecting machines, advanced analytics and the people behind them.

That shift marked the start of Industry 4.0,³ also known as the fourth industrial revolution, defined by an enhanced connectivity in the power sector. The diverse array of rapidly evolving digital technologies includes artificial intelligence (AI) and its subset machine learning, cloud computing, advancements in robotics and autonomous systems, digital twins and devices that leverage sensors, virtual reality and augmented reality.

These technologies help sharpen operations and maintenance. They improve asset performance management, predictive maintenance and outage prevention. More data captured, connected and understood means better decisions. It also means stronger safety outcomes, reduced risk, better asset monitoring and inspection and more capable teams, supported by streamlined training and skill development.

Integrating various point solutions and systems across organizations remains a challenge.⁵ Experts from the University of Alberta report in many cases, the issue starts from misalignment about what "digital transformation" means. A prominent misconception is that the terms digitization and digitalization are often used interchangeably when describing "digital transformation." The core difference, the experts note,⁶ is that while "digitization essentially refers to taking analog information and encoding into zeroes and ones," digitalization means "the use of digital technologies and of data (digitized and natively digital) in order to create revenue, improve business, replace/transform business processes (not simply digitizing them) and create an environment for digital business, whereby digital information is at the core." Digital transformation, on the other hand, encapsulates a broader and much more significant



concept — "the continuously increasing interaction between digital technologies, business and society, which has transformational effects and increases the change process's velocity, scope and impact."

Driving transformation in a sector already in flux isn't simple. It demands clarity, control and the ability to move with precision. "Energy types across the globe vary, but as a whole the common goals and expectations are the same. No matter where you are in the asset lifecycle, planning, building, operating or securing the assets, power organizations must prove they can manage their safety and environmental impacts, optimize asset performance, enhance reliability. The imperative is clear—there is no time to delay. Rapid adoption of AI strategies is imperative" said Jenny Bulach, executive industry consultant for Octave.

Implementing an intelligent information ecosystem

Building an intelligent, connected information ecosystem remains foundational to digital transformation across the power industry. “The power industry — particularly power generation — is rich in opportunities for improvements across the entire plant lifecycle, especially as we see a lot of uprating and life extension activity in the nuclear sector and continued growth in new builds of conventional, nuclear and green generation assets,” said Jay Schwartz, vice president, portfolio strategy, Octave. “There seems to be broad agreement that, for the foreseeable future, an ‘all of the above’ approach to meeting the ever-increasing demand for electricity is necessary. At the same time, uptime reliability of existing assets is being challenged more than ever. Nobody likes rolling blackouts,” he noted.

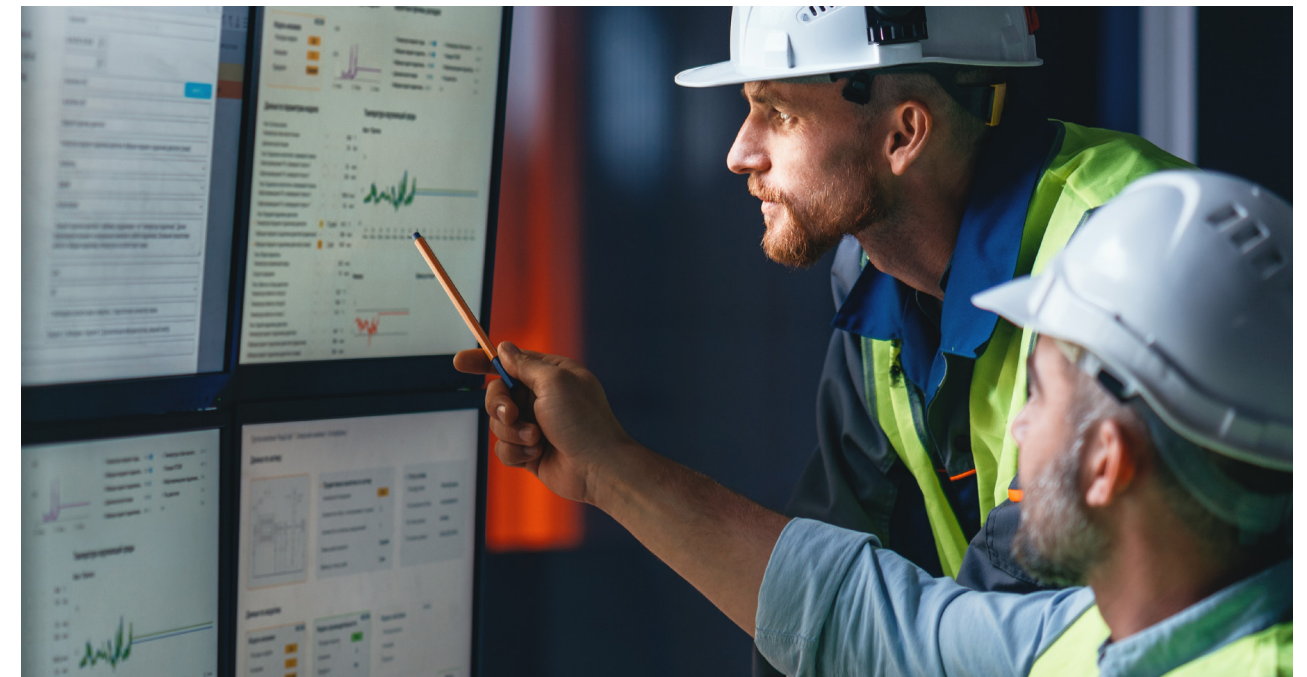
Meeting that demand takes more than technology alone. It requires the right work processes alongside proven and evolving IT solutions, whether designing new facilities or strengthening operations and maintenance as a force multiplier for a stretched workforce.

Bulach and Schwartz suggest that a cohesive focus on concerted outcomes proves imperative for a successful digital transformation. A digital transformation framework must align outcomes across the board to manage new projects, enhance competitiveness, reduce operational risks, minimize downtime, increase efficiency and ensure regulatory compliance. To achieve operational excellence, a robust digital thread must bridge gaps between various information islands, connecting operational processes, procedures, permits and data, they said. When those connections come together, organizations gain a clearer, more actionable view across the asset lifecycle.

Software plays a crucial role here. It enables intelligent design, engineering, construction, operations and maintenance — while protecting systems from cyber threats that can disrupt performance. Supporting a digital backbone requires regular analysis and

improvement of processes and workflows, along with innovations in design, engineering and manufacturing. Digital simulation and optimization push productivity further to help organizations deliver consistent, high-quality outcomes.

The balance matters. Digital assets provide a unified approach to asset management, while digital projects enable agility in response to shifting market and regulatory demands. Together, they create a steady cadence to maintain continuity while adapting to change.



An array of challenges and barriers

Establishing this ecosystem proves complex. Success depends on navigating a mix of technological, business and cultural transformations. (Table 1 next page).

Each is distinct. Complexity can be managed with the right approach, Bulach said. "Every region is facing its own mix of energy pressures—from energy growth primarily due to data centers, aging infrastructure, the retirement of massive amounts of older plants, in addition to the global shift toward cleaner, more reliable power. In this environment, the most effective digital strategies are the ones that stay grounded in reality: knowing where you are today, understanding the challenges around you and mapping practical steps to get where you need to go. Rather than copying someone else's model, power and energy organizations must build a roadmap that reflects their unique assets, constraints, markets and opportunities. That's how you drive resilience, efficiency and sustainable growth in a rapidly changing world."



Table 1: Enablers, challenges, problems and barriers to digital transformation

	Digital Technologies	Business	Society
Challenge Challenges require skill, effort or ingenuity to overcome, but they generally point to an opportunity for growth, development or achievement.	The complexity of the logistics system and core processes Adoption of new and complex technologies Legacy systems	Lack of industry-specific transformation guidelines Poor organizational environment Organizational structure Traditional business model and processes Lack of expertise to lead the digital transformation initiatives	Mistrust in digital transformation in general Resistance to change
Problem Problems pinpoint difficulties that endanger processes and work and require an immediate or long-term solution.	Poor technical/IT skills Technological compatibility Poor data quality	Lack of clear vision The inadequate strategic vision of top management Lack of coordinated digital strategy (unclear strategy) Misunderstanding of the digital transformation process Lack of change management strategy	Lack of training on new digital tools Unidentified benefits from the digital transformation Lack of required digital skills (digitally skilled employees) Lack of coordination between different stakeholders in public and private industry
Barrier Barriers hinder the achievement of goals.	Security concerns	Budget constraints Complexity	Lack of national standards and policies Lack of infrastructure and connectivity Poor legal framework Inadequate legislation for digitization
Enabler/Driver	AI and machine learning Big Data Cloud computing Cybersecurity VR and AR	Clear integrated strategy Put people in the right places Agile way of working Commit to leadership from the top through the middle management	Customers' demands Employees' demands Increasing awareness and building digital skills Standards and legal frameworks Creation and promotion of digital competencies

Source: Nazari and Musilek, Algorithms, 2023.

Modernizing legacy systems

Legacy systems remain one of the biggest barriers to progress. Outdated technology infrastructure and software applications limit data visibility, slow operations and constrain performance.

“For decades, utilities could afford to move slowly. Capacity was in excess and relying on legacy systems that changed little year to year was standard practice. That era is over,” Bulach noted. “Today’s power industry must confront the reality that outdated technologies are holding back meaningful progress. Beyond the growing cybersecurity risks that could disrupt operations, utilities are under pressure to manage the rising costs and long timelines of new plants and system upgrades—all while keeping energy affordable for both industrial and residential customers. The pace of change has accelerated. Utilities must move faster than ever to stay resilient, competitive and secure.”

That pressure presents opportunity for modernization. “The most obvious current industry strategy is moving away from coal power generation and replacing with nuclear or natural gas generation where possible, but reusing the existing site and infrastructure already in place,” Schwartz noted. Facility repowering with modern combined cycle gas turbine (CCGT) generating systems or small modular reactors (SMRs) also “has great economic and environmental appeal,” he said. “At the same time, strategies to upgrade the plant information management systems to include modern configuration management and information management technologies, and asset management systems to ensure safety, environmental safeguards, operational readiness, and plant reliability are also key opportunities for many power generation companies.” Octave’s portfolio of solutions “stands ready to go to work in both of those scenarios,” he said.



The boon and burden of big data

Among the sector's most persistent challenges is a tendency toward "data anarchy." Data from IIOT devices over the last decade has unlocked actionable insights, enabling predictive maintenance strategies, improved reliability and streamlined outage management. "In the power industry, a digital twin can model the entire grid, from generation plants to transmission lines to distribution networks—providing a real-time, data-driven view of system health. By continuously capturing and analyzing operational data, utilities gain actionable insights that help them spot early signs of equipment stress, predict failures before they happen and plan maintenance with greater precision. This not only improves overall reliability but also streamlines outage management, shortening restoration times and reducing the impact on customers," said Bulach.

But turning data into action isn't simple. Centralizing it across sites, making it accessible and securing it at scale remains a challenge. "One of the biggest challenges for power companies is having visibility of the critical systems running their business. That's true for power plants and for power distribution facilities like substations and power grids," she added.

One of the biggest challenges for power companies is simply seeing what's running across their critical systems—whether in power plants, substations or across the grid. "A holistic approach starts with the basics: creating a complete inventory of all hardware, software and firmware. This foundational step gives OT security teams the visibility they need to understand what exists, what's vulnerable, and what must be protected."

The second step for asset owners is managing risk in their facilities in a cost-effective way. This can be challenging because it takes information from many different sources to find, understand, and address thousands of potential vulnerabilities. Octave offers Octave Cyber Integrity (formerly PAS Cyber Integrity), which uses a risk-based approach that helps customers identify and prioritize the vulnerabilities that will reduce the most risk, making their facilities more secure and more resilient," Bulach said.



"Step 3, the real game-changer for the power industry is combining these security solutions with solutions that serve as the backbone to their operations, such as digital twins in all aspects of the asset lifecycle, whether be designing, building, operating or protection, digital twins are needed in all areas."

Balancing automation and a people-oriented transformation

Automation has long shaped the power sector driven by the need for efficiency, quality and scale. From early control systems to today's advanced software, the industry has steadily increased its reliance on intelligent automation. "The power generation industry has been pretty active in the innovative use of automation for many decades now. Southern Company, one of the largest power generating and grid operating companies in the U.S., utilized an analog system in the 1970's called the 'Early Bird' to optimize the use of different generating plants based on the electric demand coming from the grid," Schwartz noted. "The advent of digital control systems allowed the entire industry to improve efficiency and safety in operations, and integrated design and construction technologies enabled plants to be designed and built for optimum production efficiency and great improvements in construction speed and safety."

Now, another challenge emerges.

Up to 50% of the workforce⁸ could retire over the next decade, creating a significant knowledge gap across roles from field technicians and engineers to operations leaders. Maintaining continuity will depend on how effectively organizations capture and transfer that expertise.

But while this has been a real challenge for the power industry, opportunity exists here, "We see great opportunities for machine learning and [artificial intelligence (AI)] to augment decision support for the current and future generations of power industry professionals, both in the projects realm and in the operating assets realm," Schwartz said.

Bulach, meanwhile, noted that automation is already evolving to meet key gaps. "At Octave, we are elevating autonomy to the next level. AI is already integrated into many of our existing applications," she said. "While the world marvels at Generative AI, there are numerous applications of AI that might be less flashy but are equally transformative – from the Python framework to support AI and machine learning in enterprise asset



management processes to pressure gauge readings. This trend will continue as we introduce more products and adapt to our customers' evolving business needs," she predicted.

Regulatory, policy and stakeholder considerations

Regulatory and stakeholder pressures remain a constant in the power sector, and they're only intensifying. "The power industry receives a lot of regulatory attention, of course, but is also under a lot of scrutiny socioeconomically," Schwartz noted. "Rate increase requests are never popular in any market and environmental missteps are even less popular. At the same time, investor-owned utilities demand adequate returns, and publicly owned utilities have a duty to make the most out of the funding they receive while providing the necessary electric supply they are obligated to." Construction of new capacity is also frequently mired in permitting processes that require careful cognizance of regulatory, environmental and economic limitations. "Just look at the immense financial commitment and risk profile of attempting to build new nuclear-generating units," said Schwartz.

This blend of operational needs, regulatory and environmental expectations and project-level performance makes one thing clear: every project or outage depends on having the right information available at every decision point. The companies that rethink how they use integrated data—and put it to work across the organization—are the ones that will set themselves up for long-term success." Bulach noted the risks associated with compliance hurdles are stark. Treating stakeholder needs or compliance requirements as add-ons to your existing work is a fast track to slow downs and mistakes. Instead, they need to be built into your core business processes and into how you drive continuous improvement. From a technical standpoint, using tools that connect compliance, training and procedure management can make a huge difference. It cuts down the time spent managing documents and ensures the information your teams rely on is always accurate, consistent and part of the everyday workflow."



The hallmarks of a good digital strategy

"Today, every project is a digital project in one way or another," Schwartz noted. "It's not enough to just have electronic design, procurement and construction solutions in use. Excellent use of each of these in their respective silos will only get you so far. Having an effective integration framework and the aggressive use of the integrated design and construction technologies of choice is essential."

Schwartz suggested strategically using design solutions "to intentionally feed procurement and construction planning as well as to expedite the commissioning and start-up process is essential. Also key is to have a progressive data handover strategy so that at appropriate intervals along the project execution timeline, validated data— not just documents, but accompanying data essential to startup and operations—are handed to the startup and operations team for loading into their respective IT systems and integrating into the myriad of other uses of that data." Project managers will find "that the discipline of that data handover methodology will have positive benefits realized in the project execution phase," he said.

Bulach echoed Schwartz's call for solutions that can "work across the entire lifecycle. When your systems are integrated end-to-end, you can run automated checks that catch errors early, prevent information from getting lost between project phases and make it easier to bring project data smoothly into operations. That level of integration reduces rework, improves accuracy and ultimately helps teams move faster with more confidence."

She added "The majority of the breakdowns in data happen between the handoffs of designing, building and operating assets. Solutions need to go beyond single silos and integrate across all areas of the asset life. The results: shorter timelines, projects that are delivered on time and on budget and greater efficiency in operation."

To ensure successful digital projects, Bulach also mentioned "specialization." Power companies, EPCs and other stakeholders must rely on technologies and partners that truly understand the demands of building critical infrastructure. "There's no substitute



for proven, industry-trusted solutions—especially those with a track record of delivering major projects, including dozens of nuclear plants worldwide."

Ultimately, a robust digital strategy should be focused on growth, profitability and sustainability, but also integrate technology with business objectives. "A good digital strategy will help to achieve better, faster, cheaper and safer," Schwartz said. "Can you get there without it? Perhaps, but I wouldn't want to attempt it."

Conclusion

The global power sector faces pressure from rising electricity demand to cost constraints and increasing environmental responsibility. As a result, the industry has embraced digitalization to optimize operations and maintenance. Technologies including the industrial internet of things and Industry 4.0 reshaped the sector, bringing enhanced connectivity, sharper asset performance and informed decisionmaking.

Complex logistics, unclear transformation roadmaps and resistance to change continue to slow progress however. Legacy systems add another layer, hindering the adoption of modern digital solutions and streamlined processes.

Organizations must make sense of growing volumes of data, balance automation with workforce realities and stay ahead of evolving compliance demands. The path forward is clearer with the right partner. Organizations that align digital strategies to long-term goals (and work with experts who understand the full lifecycle) are better positioned to cut through complexity and move with confidence.

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About Octave

Octave is a leader in enterprise software, turning data into decisive action and intelligence into your edge. Our software solves for and simplifies complexity, from the design and build to operations and protection of people, property and assets – for any scope, at any scale. For decades, we've partnered with customers to sharpen performance, elevate efficiency and amplify results. From factory floors to entire cities, our solutions are tuned to scale up what's possible from day one onward.

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