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Advancing utilities' smart operations: An integrated approach to grid modernization

Introduction

As customer demand for electricity changes, driven by factors such as increased adoption of electric vehicles, renewable energy sources and smart home technologies, utilities may face significant challenges such as grid congestion, reliability concerns and the need for enhanced resilience. Enhanced operating systems and advanced technologies can mitigate these risks by optimizing grid performance and increasing stability. Rather than relying on traditional solutions like expanding bulk system capacity, grid modernization can offer a more efficient and cost-effective approach by leveraging demand-side response and management, distributed generation, and energy storage solutions.

The term grid modernization refers to transitioning the distribution grid from a one-way delivery system, originally designed for handling system peaks, and providing reliable service, into a two-way network optimized at both circuit and system levels. It is designed to enable and provide reliability, resilience, and support the the energy transition.

Grid modernization is often associated with systems such as Advanced Distribution Management Systems (ADMS), Distributed Energy Resource Management Systems (DERMS), Advanced Metering Infrastructure (AMI), Geographic Information Systems (GIS), and Outage Management Systems (OMS). While each of these systems plays a crucial role, it is important to adopt an integrated view that illustrates how these technologies can converge to generate tangible business value. By aligning these systems and others cohesively, utilities can better meet regulatory expectations and enhance shareholder value, ultimately driving their business model forward. This integrated approach not only helps to optimize operational efficiency but also positions utilities to navigate the complexities of the modern energy landscape effectively.

Ultimately, grid modernization can create a seamless connection between customer needs and grid operations. It begins with understanding and addressing customer demand more geo-spatially, which then informs grid planning and culminates in a future state where the grid can operate more intelligently and resiliently. By integrating demand-side strategies and distributed energy resources (DERs), utilities can not only mitigate risk in future grid operations but also enhance their ability to deliver safe, reliable, sustainable, and cost-effective energy solutions. This holistic approach helps to ensure that the benefits of grid modernization are realized across the value chain, from the end customer to the utility and its stakeholders.

This report seeks to explore the key challenges for grid modernization, addresses concepts for smart operations in the grid context, and the steps needed to establish a modernized and digitalized electricity grid.

Challenges utilities face when planning for grid modernization

Grid modernization is a often a complex, multi-year journey for utilities involving technical, regulatory, financial, and organizational hurdles. In addition, macro-economic pressure, changing demand, climate adaption, and technological changes can strain aging infrastructure, necessitating innovative solutions to maintain grid reliability and energy affordability. These are some of the challenges most commonly encountered:

01 Aging infrastructure

Utilities can face the challenge of managing aging infrastructure, as many operate with equipment and systems that are decades old. This necessitates substantial investment to upgrade or replace legacy assets while ensuring service continuity. The integration of new technologies with existing infrastructure often presents compatibility concerns, requiring careful coordination and strategic planning to avoid disruptions. Addressing these challenges is important for utilities to maintain reliability and efficiency in their operations.

02 Rapid adoption and integration of DERs

The rise of solar, wind, battery storage and electric vehicles is a well-known challenge. The uneven adoption of such DERs and flexible loads poses challenges in managing voltage, frequency, and reverse power flow. Utilities need advanced systems to forecast and control these variables effectively.

03 Cybersecurity and data privacy

The modernization of grids can introduce increased reliance on digital technologies, which heightens exposure to cyberthreats. Protecting customer data and critical infrastructure is paramount, necessitating robust cybersecurity frameworks and continuous vigilance. Utilities are required to comply with evolving regulations, such as NERC CIP, which add complexity to their operations. Ensuring the security of digital systems is important for safeguarding the integrity and reliability of grid operations.

04 Regulatory and policy uncertainty

Utilities must navigate multiple levels of complex regulatory landscapes, while balancing energy transition efforts with risks to energy security. This requires a nuanced approach to policy alignment and investment planning.

05 Capital investment and cost recovery, closely linked to energy affordability

Grid modernization projects can be capital-intensive and often come with long payback periods, posing a significant challenge for utilities. Securing funding and pursuing cost recovery through rates is a concern, especially in regions with stringent regulatory constraints. Utilities often have to balance the need for substantial investment with the affordability for customers, making it a persistent challenge to align financial viability with modernization goals.

06 Electrification and load growth uncertainty

Nonlinear load growth, driven by electrification of transport and buildings, may require utilities to adopt dynamic and adaptive planning scenarios to help ensure grid reliability and affordability. Demand growth is further boosted by unpredictable energy use by AI data centers.

Smart operations as the framework for grid modernization

Within many utilities, smart operations can present a distinctive opportunity. Utility executives may now recognize that ambitious targets are unlikely to be met solely through traditional, incremental progress. Yet, despite regulatory and financial constraints, incremental changes alone may be insufficient. Necessity drives innovation, making a deliberate and effective culture of innovation imperative. This culture begins with a compelling vision that clearly articulates the organization's goals and a timeline for achieving them. By continuously revising this vision and refining goals, utilities can sustain momentum, amplify the effect of coordinated innovations, and achieve significant advancements that propel the company forward.

The concept of innovative smart operations encompasses three types of automation: process automation, robotics, and Agentic AI. Process automation aims to streamline operations, enhance grid efficiency, and minimize human intervention in control loops. For example, AI can interpret signals from the field, decide on actions like opening or closing switches, and inform humans of its actions and rationale. Robotics focuses on improving safety and efficiency by deploying machines for cumbersome or hazardous maintenance tasks, such as drone inspections. Agentic AI aims to boost human productivity and decision-making, providing relevant insights in control centers or on-site. For example, AI-enabled virtual field assistants can offer engineers on-demand technical information, while AI optimizers can analyze equipment use to recommend maintenance schedules.

Accelerating automation adoption may require a "go slow to go fast" approach. A programmatic approach is needed, integrating different automation types to shift future operations and maintenance paradigms.

In that sense, grid modernization is a digital transformation effort that integrates people, processes, and technology. Smart technologies can have improved value when combined with innovative processes and a skilled workforce. Utilities can benefit from advanced algorithms for maximizing grid capacity and AI solutions that improve productivity and provide operational insights. Optimizing processes can be crucial for enhancing asset inspection and maintenance. Many utility leaders are now setting long-term goals to improve reliability, affordability, and sustainability, while delivering shareholder value, creating a vision for a smart grid.

Visionary leadership can be key to fostering an innovation culture. Building capabilities where innovation is valued, and failures are viewed as learning opportunities is important. Celebrating successes and analyzing failures helps enable utilities to learn, adapt, and achieve better outcomes. This approach to digital transformation can help drive future grid modernization, helping to ensure utilities meet evolving customer and stakeholder demands.

Charting a course for grid modernization through smart operations

Practical steps utilities could consider when embarking on their grid modernization journey include:

1. **Establish a clear vision tied to corporate strategy**
   Unite leaders of various smart operations and digital transformation initiatives by establishing an overarching vision for a holistic grid modernization program. Tying this vision back to the utility's business objectives helps to ensure that it meets long term goals. Provide clear direction to leaders on:

   - How far should they go and how fast?
   - What are the expected outcomes and how do they relate to the corporate strategy and the business objectives the utility is looking to achieve?
   - How do various automation initiatives connect to one another?
   - How do they relate to adjacent initiatives?
   - What are the initial building blocks? What comes first? What comes second?

2. **Align information technology and operating technology**
   Operating technology (OT) does not stand alone; it must align with Information Technology (IT). Ensure enterprise transformation and grid modernization approaches are coordinated, integrating OT and IT systems to maintain the accurate asset data that's essential to predictive maintenance and power f low analytics.

3. **Asset management thinking beyond operations and maintenance**
   Grid modernization, automation, and robotics can enhance asset management by transitioning from "run to fail" strategies to predictive and proactive maintenance. Effective asset management requires understanding asset locations, conditions, connectivity, and criticality. Incorporating sensors and automation enables the real-time data collection, that is vital to predictive analytics and to reducing downtime and enhance reliability. Robotics can revolutionize grid operations by automating routine inspections and maintenance, improving efficiency, and enhancing safety. By integrating these technologies, utilities can maintain and optimize their infrastructure more effectively. Predictive and proactive maintenance helps to ensure assets are kept in optimal condition, extending their lifespan and reducing costs. This intelligent approach ties back to the core principles of asset management, ensuring utilities can deliver reliable service while adapting to the evolving demands of a modern energy landscape.

4. **Leverage data with purpose**
   Intelligent automation requires high-quality data inputs. Establish strong processes to produce good data. Organize a data model that underpins operations with an asset hierarchy and data standards to flow highquality data from sensors and field activities to operations teams, upstream and downstream assets, ERP systems, databases, advanced analytics, and AI agents. The criticality of the assets, per asset management standards such as ISO 55000, will play a large role in determining what data flows where.

5. **Modernize workflows, not just the grid**
   In the rapidly evolving landscape of utility operations, modernizing workflows is as crucial as upgrading the physical grid itself. By integrating new grid-data

streams, utility companies can enhance their core business processes, allowing for more agile and responsive operations. These data-driven insights can enable companies to transform work execution, making it more efficient and effective. Setting clear goals and metrics is essential to accelerating workflows, particularly in areas such as system planning and outage resolution. By doing so, utilities can not only improve service delivery but also enhance customer satisfaction and operational resilience. Moreover, modernized workflows can lead to better resource allocation and reduced operational costs, ultimately contributing to a more sustainable and profitable business model.

6. **Embed cybersecurity from the ground up**
   Security is a foundational element, not an add-on. Hyper-connected grids require zero-trust architecture, verifying everything and assuming nothing. Segment OT systems from IT, use air-gapped backups for critical controls, and employ AI-driven threat detection for rapid anomaly identification. Regular stress-testing and standards compliance like NIST 800-82 reduce risks, averting potential catastrophes.

7. **Leverage digital twins**
   Digital twins offer a revolutionary approach to managing and optimizing utility systems by creating a virtual replica of physical assets and processes. By simulating impacts across the system in a digital environment, utility companies can overcome the limitations of incrementalism and make more informed decisions. This technology allows for a comprehensive assessment of costs and benefits associated with upgrades before any physical piloting takes place, ensuring that investments are both strategic and cost-effective. Furthermore, digital environments provide a platform for virtual stress-testing system links, minimizing risks associated with unforeseen disruptions. By leveraging digital twins, utilities can enhance predictive maintenance, optimize asset performance, and improve overall system reliability, paving the way for smarter and more resilient operations.

8. **Revamp governance and risk intelligence**
   As utility companies increasingly adopt intelligent automation, understanding the associated risks becomes paramount. Revamping governance and risk intelligence involves establishing frameworks tailored to specific tasks, enabling expedited decision-making and prompt risk mitigation. This proactive approach can ensure that potential threats are addressed swiftly, maintaining operational integrity and continuity. Upskilling personnel is crucial in this process, as it empowers them to differentiate between significant and minor risks, thereby driving program progress and innovation. By fostering a culture of continuous learning and adaptability, utilities can enhance their risk management capabilities, ensuring that they remain agile and responsive in the face of evolving challenges. Ultimately, robust governance and risk intelligence can contribute to a more secure and forward-thinking utility operation.

9. **Alliances and the strength of the ecosystem**
   In the context of grid modernization, alliances and ecosystems play a crucial role in driving innovation and achieving sustainable outcomes. Utilities should collaborate with technology providers, policymakers, and other stakeholders to create an ecosystem that supports the integration of advanced technologies and processes. These relationships can enable utilities to leverage external knowledge and experience, share risks, and accelerate the adoption of new solutions. By fostering a collaborative environment, utilities can enhance their capabilities, improve service delivery, and meet the evolving demands of their customers and stakeholders.

Conclusion

Utilities today face the dual challenge of expanding and enhancing their systems while maintaining reliability, affordability, and sustainability. Grid modernization offers a pathway to address these challenges by integrating advanced technologies, innovative processes, and skilled workers. By adopting a holistic approach that encompasses smart operations, alliance relationships, and adaptive planning, utilities can navigate the complexities of the modern energy landscape and deliver across the value chain. This transformation not only supports the resilience and efficiency of the grid but can also position utilities to meet future demands and regulatory expectations effectively.

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