Why the Utility of the Future Requires a Digital Grid

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– International Energy Agency

Introduction: The Energy Transition is On

Getting 100-plus countries to agree on anything is a big challenge. Yet, at the recent COP28 United Nations Climate Change Conference in Dubai, 132 nations endorsed a pledge to triple the world's renewable energy capacity to 11,000 gigawatts by 2030.

The agreement came at a time of historic growth in renewable generation—from small, distributed energy resources (DERs) like rooftop solar connected to the distribution grid to large-scale wind, solar and energy storage projects on the transmission system. According to the International Energy Agency (IEA), 507 gigawatts of new renewable capacity was added to grids around the globe in 2023, an increase of 50 percent compared to 2022.

How to successfully manage this rapidly increasing DER and large-scale renewables capacity are key challenges facing electric utilities around the world. The task's importance will only intensify as the renewables' influx continues, impacting every aspect of how a utility does business—from grid planning to real-time operations, to asset management and end consumer engagement. And the growth isn't slowing down, with economics and government policy continuing to incentivize market growth, the impact of renewables will only accelerate.

For example, the Inflation Reduction Act in the U.S., the European Union's Green New Deal and incentives aimed at scaling renewables in India, provide billions in government support for clean energy. Government incentives combined with the improved economics of renewables and DERs are both driving the adoption of electric vehicles (EVs), heat pumps and other electric technologies, and dramatically increasing demand for electricity. Indeed, McKinsey & Company forecasts that absolute electricity use across Europe will rise from 2,900 TWh in 2021 to 3,700 TWh by 2030.

Digital Technologies and the Resilient Grid of the Future

Managing and supporting the clean energy transition is just one reason utilities must work to create a resilient, sustainable and intelligent grid. To build that grid of the future, utilities are adopting advanced digital tools to achieve equally important and interconnected objectives, including:

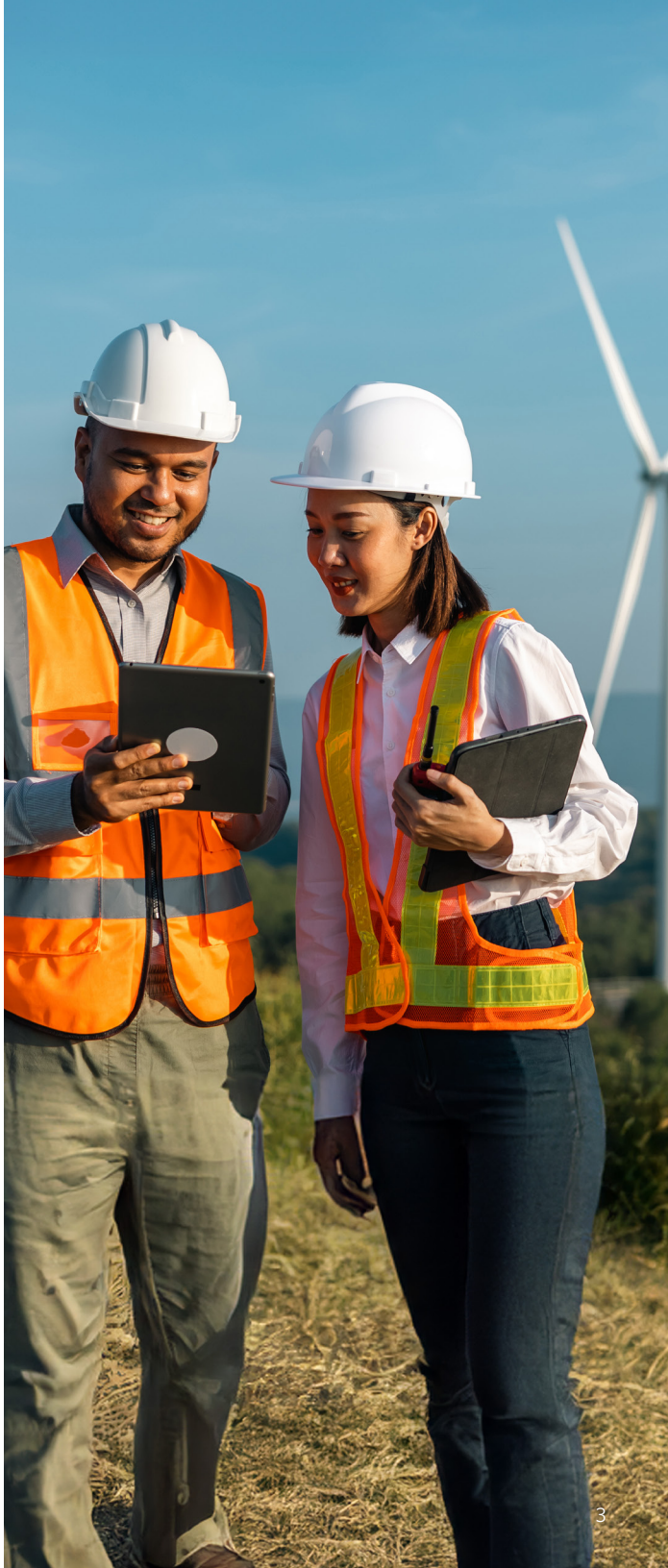
1. Improve Operational Excellence and Safety

Even as electric utilities navigate an unprecedented amount of change, their core mission remains the same: The generation and delivery of reliable, safe, increasingly clean and affordable electricity.

But the tools, resources and expertise utilities need to achieve that mission are changing. For example, worldwide demand for electricity is forecast to double by 2050. Utilities simply cannot meet that skyrocketing demand by following the traditional approach of generating electricity with large fossil fuel power plants and sending it in one direction to customers.

Vastly improved monitoring, automated control and forecasting are needed for electric utilities to maintain a reliable grid able to face bi-directional power flows, such as DER owners producing energy that is fed back onto the grid. The proliferation of consumer grid-edge technologies like EV charging infrastructure, rooftop solar and smart thermostats also put more pressure on utilities to engage and satisfy customers whose electricity usage will impact utilities' ability to cost-effectively ensure grid reliability.

The addition of large volumes of renewables also leaves the grid vulnerable to instability. The rotating turbines and generators of traditional power plants provide inertia that keep the grid stable when there are sudden changes in supply and demand. Renewables don't provide the same level of inertia. In extreme cases, this can lead to power outages, though more common are voltage and frequency deviations that must be addressed using energy storage and advanced control strategies.

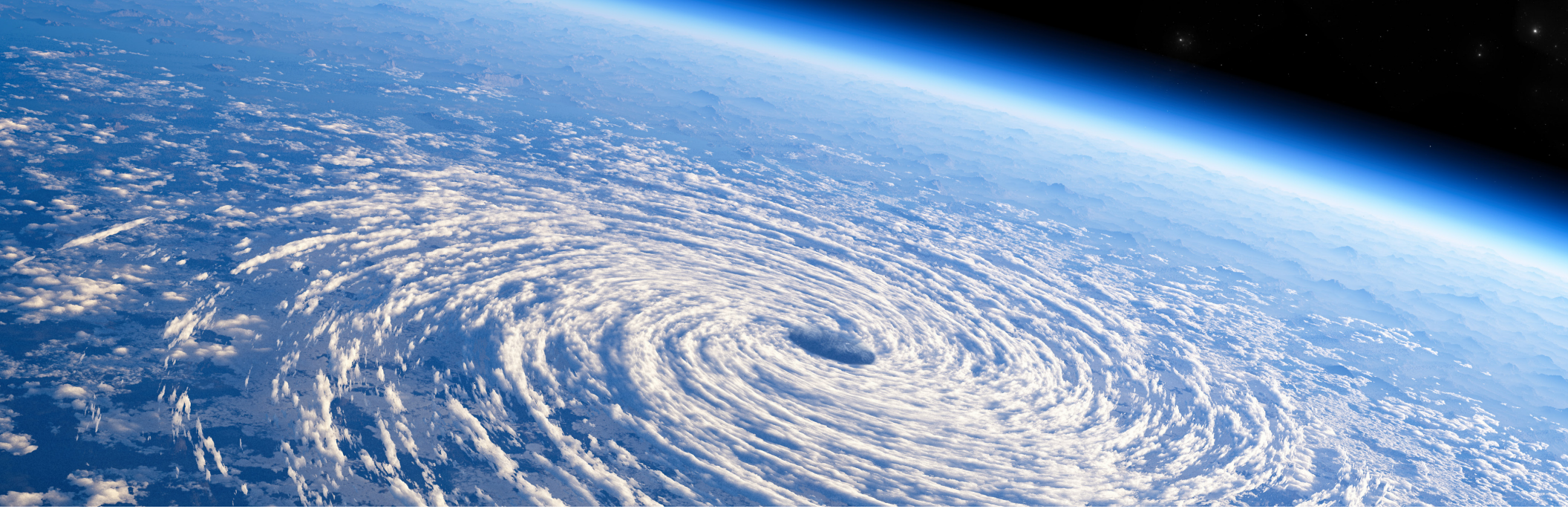


2. Mitigate Vulnerabilities

Increasing deployments of grid assets with communication capabilities and sensors to monitor renewables also elevates the priority of cybersecurity. The threats posed by cyber criminals are real. The IEA described the frequency of global cyberattacks as reaching "alarmingly high levels," and also noted the industry's capacity to prevent and respond to these attacks as being stymied by "difficulties in finding and retaining the skilled professionals needed to defend themselves". Globally, the IEA reported a doubling in cyberattacks on utilities between 2020 and 2022, while U.S. utilities have experienced a nearly seven-fold increase in cyberattacks since 2019.

Cybersecurity isn't the only area in which the power & utilities industry needs to invest. As the grid becomes more distributed and the convergence of operational technology (OT) and information technology (IT) accelerates, the capabilities needed to collect, store and analyze data become essential to effective grid planning and management. One acknowledgement of this pressing need is the Electric Power Research Institute's (EPRI) Grid Model Data Management Working Group, which brings together utilities, academics, software vendors and other stakeholders to develop and maintain accurate and accessible grid models.

Utilities must also contend with the reliability challenges of a grid that is simultaneously modernizing and aging. In Europe, 40 percent of the distribution grids are more than 40 years old.[1] This increases the risk of unplanned outages and makes it more difficult to integrate renewable energy and meet rising electricity demand. In its most recent report card on U.S. infrastructure, the American Society of Civil Engineers (ASCE) gave the nation's electricity grid a C-, due in large part to aging equipment.



3. Strengthen Grid Resilience

With power grids facing unprecedented challenges from climate change-fueled extreme weather, utilities must embrace digital solutions to improve operational excellence and create stronger, more reliable and more resilient grids. In the U.S., over 80 percent of power outages between 2000 and 2021 can be attributed to severe weather. And the annual number of weather-related outages increased by approximately 80 percent between 2011 and 2021 as compared to between 2000 and 2010.

Extreme weather is negatively impacting Europe and other regions of the world, too. According to the European Environment Agency, extreme weather was responsible for financial losses of nearly 650B Euros in EU member states between 1980 and 2022. The agency concluded that future losses are likely to increase with weather events becoming more severe and more frequent.

4. Manage the Electrification and Clean Energy Needs of the Future

A fundamental question for electric utilities is whether their existing operational systems can handle the many challenges facing the electric power system. The stakes are high. Delivering on the promise of increasingly clean, safe and reliable electricity is fundamental to utilitiesfinancial performance as well as the regulatory and consumer confidence needed to make necessary investments to modernize the grid.

The stakes go beyond utility financial performance and rate case approvals. The electrification of transportation, building heating and cooling, industry and other sectors is widely seen as the best strategy to decarbonize and drive economic growth. But the experience of utilities struggling to unclog interconnection queues, deploy virtual power plants (VPP), manage peak demand and protect grids against extreme weather and cyberattacks has made it clear that status quo technologies and tools are inadequate.

There is a growing recognition that utilities must deploy advanced digital systems to achieve all that is being asked of them. For example, Bloomberg New Energy Finance (BNEF) estimates that reaching global 2050 net-zero goals will require $21T USD in power system investments, including $5.1T USD in digitalization. Unfortunately, many utilities continue to rely on homegrown or outdated software that leaves them vulnerable to outages, cyberattacks and regulatory fines. The lack of sophisticated digital grid technologies also prevents utilities from fully leveraging the benefits of data collection and analysis to manage the grid, accelerate renewable interconnection or engage customers.

Advanced Digital Solutions to Serve Broad, Varied Customer Base

Digital Grid Management typically encompasses a number of capability areas for stakeholders across the electric power system. These include:

- Generation Management Systems (GMS)
- Transmission Management Systems (EMS)
- Advanced Distribution Management Systems (ADMS)
- Outage Management Systems (OMS)
- Distributed Energy Resource Management Systems (DERMS)
- Historian and Data Management
- Pipeline Management Systems
- SCADA
- And more

When used together, these systems provide the needed control and visibility for utilities to produce, transmit and distribute power while maintaining grid stability and reliability—even as demand increases and variable renewable generation proliferates.

To reach global 2050 net-zero goals will require $21T USD in power system investments.

– Bloomberg New Energy Finance (BNEF)

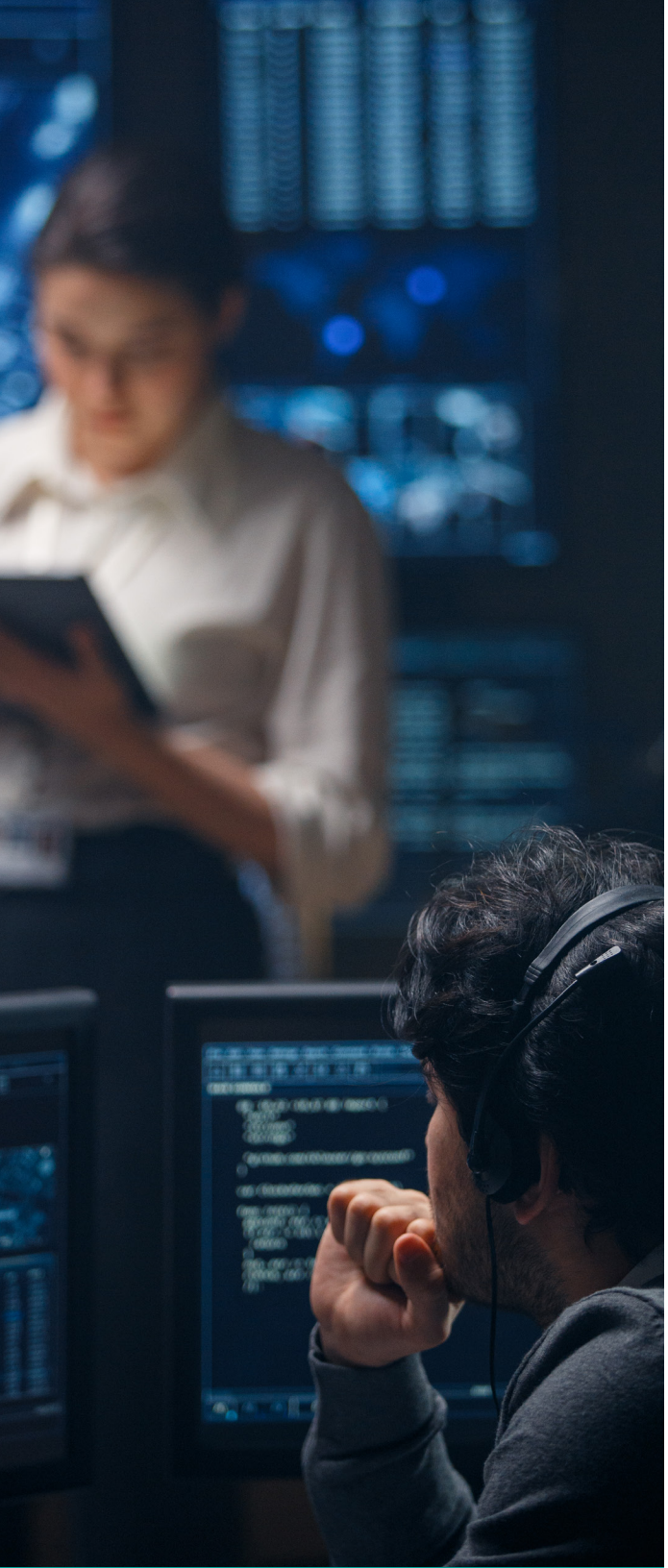
Generation utilities can leverage GMS to manage terawatts of power from conventional power plants as well as smaller but still significant wind and solar farms producing hundreds of megawatts. Digital controls provide utilities with visibility and control to plan and dispatch electricity from a broad portfolio of generation resources in both regulated and deregulated markets.

Transmission system operators are leveraging digital solutions like GMS and EMS to balance the bulk electric grid by safely transporting increasingly large amounts of power. Not only is the total amount of power larger, the proportion of intermittent renewables that cause congestion and inertia issues also is increasing and must be addressed by processing growing grid data and making intelligent control decisions through automation.

Distribution system operators can utilize ADMS to model an increasingly complex distribution system and enable operators to monitor the real-time flow of power between the high-voltage transmission grid and end consumers. ADMS systems include a wide range of automation to manage voltage, switching and fault management such as an Outage Management System (OMS).

Distributed Energy Resource Management Systems (DERMS) ensure the integration of small, grid-edge Distributed Energy Resources (DERs) like rooftop solar panels, batteries, electric vehicles and smart home devices into the grid, allowing for seamless coordination and efficient utilization of these flexible loads for both Transmission and Distribution utilities.

A SCADA platform and purpose-built OT applications offer a comprehensive solution for real-time monitoring and control of electric, gas or water networks. Inclusive of a wide range of communication protocols, integration capabilities, as well as a robust data historian, the scalability and modular functional capabilities can be used for a variety of both utility and industrial applications.



Digital Grid Case Studies

Generation, transmission and distribution utilities around the world are deploying highly scalable, digital solutions to tackle pressing challenges and build a pathway to the self-optimized grid of the future. Here are four customer success stories:

SMUD® | Distribution Utility: SMUD Minimizes Risks, Maximizes Benefits of DERs

California is a leader in its efforts to decarbonize. The state aims to achieve net-zero carbon emissions across its entire economy by 2045, in large part by transitioning the electricity grid to be carbon-free by 2035. In a state serious about decarbonization, SMUD stands out. In fact, SMUD seeks to be 100 percent carbon-free by 2030, the most ambitious decarbonization goal of any large utility in America.

Deployment and smart use of DERs like rooftop solar, energy storage and demand-side resources are key to SMUD's effort to engage customers in decarbonization. Across SMUD's 900-square-mile service territory, more than 20,000 solar systems produce nearly 280 megawatts of clean energy, 6,500 EVs, 83,000 residential demand response customers and 129 energy storage units.

The company deployed an Advanced Distribution Management System (ADMS) including a Distributed Energy Resource Management System (DERMS) to provide operators visibility to quickly assess both positive and negative DER impacts on its network as well as a menu of actions to prevent voltage and frequency violations and potential damage to grid infrastructure.

While ADMS and DERMS are essential to SMUD's day-to-day operations and its ability to model its grid and connect more DER to its network, it also has important longer-range benefits. For example, ADMS & DERMS can support improved planning, including the deployment of DERs in strategic locations on the grid to eliminate or delay the need for expensive upgrades. DERMS also can provide new business opportunities for SMUD customers by enabling DER participation in wholesale electricity markets.

Since implementing DERMS as part of its ADMS, SMUD has provided its operators with the real-time visibility they need to know how much DER generation and load is connected as well as the positive and negative impacts DER has on normal distribution operations. This real-time visibility provides operators with the information they need to optimally manage DERs for customers, the grid and maximum decarbonization.

Distribution Utility: Small Solar and Big Impact for Australia's Jemena

Homeowners in sunny Australia are over three times more likely to have a rooftop solar system than a backyard swimming pool. The combination of a mature solar industry, extraordinarily low installation costs and, yes, sunny skies has translated into over one-third of Australian homes having solar panels.

The proliferation of so much rooftop solar puts a lot of pressure on utilities like Jemena, which owns and operates a significant portion of the distribution grid north-west of Melbourne in the state of Victoria, where rooftop solar set a record by providing over 65 percent of all the state's electricity during a 30-minute period on the last day of 2023. Not only must Jemena facilitate customer demand for rooftop solar that can connect to the distribution network, but it also must take proactive steps to reduce overall network costs, maintain grid reliability and ensure employee and consumer safety.

One important step Jemena has taken to meet the expectations of customers and the requirements of regulators is through its deployment of a state-of-the-art ADMS, including FLISR (fault location, isolation and service restoration) capabilities. The FLISR runs on top of Jemena's existing SCADA fixed asset communication and doesn't require any

device-to-device communication. It also can incorporate devices from any manufacturer. Since it went live in November of 2021, the goal of the FLISR implementation was to restore customer power within three minutes, which is the acceptable threshold set by Jemena's regulators.

Accomplishing this goal in a network with so many small solar systems require a high level of grid visibility and advanced capabilities such as real-time power flow analysis. It also demands a sophisticated FLISR algorithm and a high-level of grid device automation to respond to outages quickly and effectively. Since its initial deployment, Jemena's FLISR system has completed more than 25 auto-restorations, all within the required three minutes. Detailed post-event reports help Jemena understand how many customers were impacted, whether a FLISR auto-solution was available, how many customers were restored and the financial benefits of the automatic switching.

The FLISR rollout is part of Jemena's longer-term digital grid vision, which includes the use of dynamic voltage management, dynamic operating envelopes and a DERMS to enable more DER to connect and operate in ways that benefit customers and Jemena.

Generation Utility: Power System Visibility Helps Grid-India Match Renewables and Demand

In 2023, India surpassed China as the most populous nation on earth. The sprawling South Asian country has over 1.4 billion people, a rapidly growing economy and is expected to add another 250 million people by 2050.

At COP26, India pledged to achieve net-zero carbon emissions by 2070 and has set the goal of installing 500 gigawatts of renewables by 2030. Much of the responsibility for rapidly accelerating the deployment of clean energy while maintaining grid reliability will fall on Grid-India, the independent system operator (ISO) of the world's largest synchronous electricity grid. With a generation capacity of 425 gigawatts—including growing levels of large and small intermittent renewable generation—Grid-India needs tools that allow it to accurately forecast weather dependent generation sources like wind and solar.

Full visibility across its broad geographic footprint is a must for Grid-India. It's critical to be able to do the necessary short-term, day ahead and longer-term planning required to match supply and demand in a way that achieves economic, network and clean energy objectives. Transparency is also essential because Grid-India works in tandem with state and regional Load Dispatch Centers (LDCs), that are ultimately responsible for buying and transmitting enough power to meet customer demand.

Grid-India has been able to achieve these objectives through an ambitious deployment of digital grid capabilities, including a SCADA system, Generation Management System (GMS), Energy Management System (EMS), data historian, and integration with third-party systems that provide data for optimized scheduling and dispatch. An integrated solution along with the development of a common information model (CIM) has helped enhance visibility and control across a broad geographic area and a diverse portfolio of generation assets.

Since the initial deployment of digital grid management technologies, Grid-India has been able to successfully integrate operations with 68 local and regional LDCs and establish international interconnections with Bhutan, Bangladesh and Nepal. The company is using advanced visualization capabilities to track renewable energy generation and reliably match supply and demand. Grid-India has accomplished this while ensuring robust cyber and physical security across its network.

Transmission Utility: Real-time Resource Utilization Helps TenneT Decarbonize the Netherlands

Few organizations in the world are experiencing the challenges and opportunities of the energy transition more acutely than TenneT, a Netherlands-based grid operator with a 25,000-plus kilometer transmission network and over 40 million end users in Germany and Holland. At one level, TenneT's goals to exactly match the supply and demand of electricity, facilitate an efficient and stable electricity market and operate a reliable high-voltage transmission grid haven't changed.

But the marketplace dynamics and emerging technologies the transmission system operator (TSO) must balance are changing at a pace that requires continuous innovation to achieve those objectives. For example, as part of the country's pledge to reach net-zero greenhouse gas emissions by 2050, the Netherlands has committed to reduce emissions 55 percent by 2030, 70 percent by 2035 and 80 percent by 2040.

To achieve those goals, TenneT is relying on a large and rapid buildout of renewable energy. This includes connecting nearly 40 gigawatts of offshore wind in both the Netherlands and Germany by 2030, and Europe's fastest per capita adoption of solar, significantly small residential and commercial rooftop PV. At the same time, European electricity markets have become increasingly more interconnected, which is helpful for ensuring resource adequacy but adds complexity to TenneT's grid operations.

TenneT has embraced digital grid capabilities to achieve the mission of orchestrating real-time power generation resource utilization across its broad and diverse network. This includes leveraging digitalization to enhance the grid flexibility provided by demand-side management, energy efficiency, energy storage and flexible supply.

Increased automation and modernization of TenneT's SCADA and EMS enable it to seamlessly manage the complexity of a quickly changing network while also protecting against disturbances from extreme weather and cyberattacks.

A Digital Grid Management Buyer's Guide

Even when utilities understand that digital grid management capabilities are essential to achieve company and customer goals, they still face the dilemma of choosing solutions that solve immediate challenges and can scale to deliver long-term value. Software vendors of all sizes make lots of claims about their products. But it's important for utilities to be discerning and ask vendors tough questions.

Following are some key capabilities that power companies and utilities should look for when choosing a real-time operations technology provider:

- Enterprise platform approach that supports modularity and scalability for future growth
- Standard product-oriented strategy enabling an evergreen system approach that allows faster and less expensive upgrades
- Robust software development with secure coding practices
- Active user community with influence on product direction
- Transparent product roadmaps to ensure compliance with market, regulation and audit requirements
- Customer-focused culture that fosters long-term partnership
- Comprehensive support program
- Proven and certified cybersecurity management plan

Conclusion: Powering the Future, Empowering the Digital Grid

While the volume and pace of change facing electric utilities is daunting, the opportunities for load growth and leading the transition to a decarbonized, healthy and prosperous tomorrow are unprecedented. Managing and mitigating the risks while successfully turning challenges into opportunities demands rapid adoption of digital technologies.

AspenTech's Digital Grid Management solutions support the evolution to an intelligent self-optimizing grid that utilities can monitor and control in real-time to provide secure, reliable and affordable service. Deployment of these solutions and support from AspenTech can accelerate the hardening of critical infrastructure to mitigate adverse events, expand renewable energy capacity reliably, scale to support automation and, empower consumers to actively participate and benefit from greater, more diverse market opportunities and services.

Citations:

[1] European Commission, Commission sets out actions to accelerate the roll-out of electricity grids, November 28, 2023

About Aspen Technology

Aspen Technology, Inc. (NASDAQ: AZPN) is a global software leader helping industries at the forefront of the world's dual challenge meet the increasing demand for resources from a rapidly growing population in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation and maintenance lifecycle. Through our unique combination of deep domain expertise and innovation, customers in asset-intensive industries can run their assets safer, greener, longer and faster to improve their operational excellence.

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