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Overcoming Challenges to Safer, More Secure Adoption of Distributed Energy Resources (DERs)

LET’S GO

Table of contents

Introduction

The traditional grid architecture is comprised of utility-scale power plants predominantly using fossil fuels with aging transmission and distribution infrastructure. Power producers are investing in renewable power production, more efficient and localized transmission technology, with an array of distributed energy resources (DERs). Consumers are also adding to capacity through installation of small- to mid-scale solar arrays, small wind turbines, stationary energy storage systems (ESS) and bidirectional electric vehicles (EVs) that can supplement on-site electric use as well as send power back to the grid.

As DERs are integrated into the built environment and the shared power grid, safety and security challenges must be addressed to foster continued progress toward decarbonization and energy independence. Some of these problems include grid code compliance, interoperability of DERs with existing grid power production sources, generation management systems and cybersecurity threats.

Let's explore these challenges — and examine strategies to support safer, more secure distributed generation utilizing a variety of DERs.

MARKET SPOTLIGHT

DER market growth

The expansion of DERs implementing a variety of renewable technologies, such as battery energy storage systems (BESS) and EV battery technologies, is diversifying supply types. Growing government incentives support this technology, accelerating its pace of adoption.

The DER market is predicted to grow at a compound annual growth rate (CAGR) of 14.8% through 2034[1] as the global economy shifts toward rapid decarbonization to reach net-zero emissions by 2050.

Many power purchasers (individuals, corporations, municipalities, etc.) are setting ambitious decarbonization targets to meet these goals. These include meeting regulatory compliance requirements, realizing operational savings and improving building resilience amid increasingly erratic weather patterns. These goals are driving the move toward electrification and the use of DERs.

Learn about safety and security obstacles

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Challenges

Realizing the potential of DERs may increase existing challenges and introduce new challenges in managing and protecting the stability and resilience of the grid ecosystem. Stakeholders, including regulators, power producers and manufacturers, must understand and navigate risks that negatively impact safety, reliability and performance.

Physical safety

Distributing power generation and storage also distributes safety risk. BESS and EV batteries can experience thermal runaway, leading to catastrophic failures that can damage property and claim human lives. In 2024, a series of fires at BESS facilities in the San Diego metropolitan area resulted in evacuation orders, the release of toxic gases, and more regulatory scrutiny about how, when and where to site energy storage projects. High-profile fires caused by EV batteries (largely from batteries used in e-bikes and other consumer goods) have resulted in scores of deaths, property damage and hazards for first responders. Energy storage equipment damaged by fire or physical impact can pose fire, chemical and energy hazard risks weeks after a failure, even after the initial event was mitigated by first responders. The storage, removal, reclamation and proximity to people and structures must be considered following a failure event.

Stability and reliability

Renewable energy production fluctuates, so energy storage is critical to meet variable demands. However, coordinating DER activity throughout a distributed grid remains an ongoing challenge due to a lack of behind-the-meter visibility into the behavior or locations of customers. This can lead to oversupply, overvoltage and subsequent grid congestion. Conversely, increasing demand from electrification, coupled with limited 24-hour availability of DERs, can lead to overload, resulting in undervoltage, underfrequency and other forms of grid instability. DER equipment requirements have expanded to require grid support and smart DERs to quickly respond to abnormal grid voltage and frequency events to counteract the abnormality and increase grid stability and reliability.

The first era of grid-interactive inverters operated on relatively simple principles, allowing power to flow into the grid if voltage and frequency levels were within normal ranges. If the grid voltage and frequency levels changed outside of nominal, distributed generation was required to disconnect and wait for five minutes of grid stability before it was allowed to reconnect and resume export.

As distributed generation and DERs have scaled, their expansion requires more advanced supportive devices.

Adopting more sophisticated power control systems allows utilities to continuously monitor grid conditions and maintain adequate control over energy generation, storage and distribution. These systems can analyze data from various DERs and adjust operations accordingly to maintain stability. For instance, modern inverters can dynamically manage various levels of grid interaction and adjust output based on real-time conditions to prevent overwhelming the grid, enhancing reliability. They can also provide ancillary services, such as reactive power support, which are vital for maintaining grid stability.

Similarly, electric vehicles (EVs) benefit from more advanced inverters and power control systems to promote safer, effective integration into grids as they charge. As EV adoption rises and EV charging demands grow, more advanced power control systems can help reduce grid stress. Advanced power control systems also help enhance the safety of other applications, like bidirectional charging, which requires high levels of dynamic interactivity between devices.

That said, new products may also require new testing and certification for safety and efficacy and even new standards to promote sound integration with the grid and interaction with other devices.

Interoperability

The pace of innovation in energy transition technology is extremely rapid. Often, emerging equipment and systems do not work well with legacy equipment. Emerging standards developed by a broad coalition of stakeholders seek to rectify interoperability issues among hardware and software while continuing to support competition and innovation.

Key stakeholders can advocate for and adopt standardized communication protocols across DERs to help support safer, sound and seamless integration and interoperability. Manufacturers and regulatory bodies can engage with utilities and other stakeholders tasked with managing and promoting the development and implementation of more consistent, universal communication protocols. Utilities and manufacturers can also invest in tools and processes that validate the interoperability of DER devices. This includes developing test protocols that confirm devices communicate effectively and respond to grid conditions as intended under normal and foreseeable abnormal operating conditions.

Cybersecurity

While distributing power production coupled with energy storage results in a more flexible and modernized grid, it also expands the potential risk of cybersecurity vulnerabilities.

In 2023 and 2024 alone, utilities in the U.S. saw a 70% spike in cyberattacks, and the volume of attacks between 2020 and 2022 increased by 118%.[2] Researchers have uncovered vulnerabilities in software systems used for DER management,[3] and "white hat" hackers have demonstrated the ability to bypass firewalls and remotely take control of DERs such as rooftop solar panels.[4]

While utilities are adept at responding to many threats, warding off digital attacks is an ongoing and challenging process that must be proactively managed, as cybersecurity will likely continue to be a moving target. In 2024, then-FBI Director Christopher Wray warned the U.S. House of Representatives that critical infrastructure, such as electrical grids, is particularly susceptible to attack by foreign adversaries and cybercriminals.[5]

Organizations like the U.S. Department of Energy (DOE) work to promote cybersecurity in DERs. In 2024, the DOE and the National Association of Regulatory Utility Commissioners (NARUC) collaborated on an initiative to establish cybersecurity baselines for electric distribution systems and DERs such as solar, wind and energy storage systems.

New stakeholders entering the DER landscape, whether as manufacturers or owners and operators of power generation and storage equipment, may not have existing cybersecurity expertise. This can lead to the rollout of vulnerable systems that are ill-equipped to defend against cyber threats. In addition, the rapid rate at which some DER technologies are scaling may outstrip stakeholders' ability to keep up with needed cybersecurity measures and evaluate, test and certify new products to cybersecurity safety standards, leaving gaps that can be exploited.

Manufacturers and utilities need to raise the bar for performance and security on installations with equipment such as photovoltaic inverters, electric vehicle chargers, wind turbines and fuel cells.

Regular risk assessments allow utilities and manufacturers to adapt cybersecurity strategies based on the latest threat intelligence and new technological developments. Involving as many stakeholders in risk assessment processes as possible also helps enhance security.

Collaboration and coordination

Original equipment manufacturers (OEMs), power producers, regulators and other stakeholders involved in grid management must be responsive to one another as they navigate challenges introduced by DERs and manage speed, safety and sustainability in the integration and operation of devices and systems.

Ongoing standards development

Energy transition technologies are evolving quickly, and relevant industry standards and jurisdictional codes must be updated to keep pace and address interoperability, safety, cybersecurity and other concerns. Well-balanced standards development technical committees and working groups are crucial to the thorough development and adoption of requirements that meet the needs of all involved. Manufacturers must also understand how to demonstrate compliance with new standards as testing, assessment and certification requirements change.

Complex regulatory landscape

Navigating various regulations across jurisdictions can hinder compliance efforts and slow deployment. Each state, region, electricity market or other jurisdiction may have its own rules governing DER integration, resulting in an intricate web of requirements. Inconsistency can create confusion and inefficiencies, as utilities and manufacturers must tailor their operations to meet different regulatory standards. Additionally, because DERs and their owners may operate across state lines, utilities and manufacturers may need to coordinate compliance with multiple regulatory entities, which could lead to delays in project approvals and increased costs.

Proactive participation in standards development processes can help stakeholders stay updated on, prepare for and guide the development of regulations that reflect the requirements and opportunities introduced by DERs. Robust training programs that cover regulatory compliance, safety standards and the latest technological advancements can help personnel involved in grid integration and management navigate regulatory compliance more effectively and stay current with evolving requirements and industry best practices, in turn, helping to reduce noncompliance risk.

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> Manufacturers of energy-producing technologies need an understanding of how to comply with the utility’s requirements for interconnection. Some countries have just a few utilities over a relatively small geographical footprint with similar challenges. The U.S. has more than 3,300 utilities spread across a vast landscape all with unique needs. We help customers understand complex — and sometimes surprising requirements to help them obtain market access.
>
> **Scott Picco**
>
> Principal engineer,
> Energy and Industrial Automation

Deep dive on interoperability and compatibility

Interoperability and compatibility in EV charging systems

If you take a deconstructed view of an EV, you can envision the use of its mobile battery and high-power inverter as a potential high-capacity ESS DER that could be used as robust energy storage and generation for multiple purposes. Increasingly, EVs now feature onboard vehicle-to-grid (V2G) bidirectional charging technology that can export power to the grid or local loads, such as in a driver's home (vehicle-to-home, or V2H). Realizing the true potential of this technology has been hampered by a lack of true consensus standards that cross-cut industries (DER, power distribution and automotive industries) as well as vast differences in national regulation requirements between DERs and automotive vehicles. This restricts compatibility due to a lack of interoperability in the market.

EV charging has been problematic, resulting from significant variability among chargers and charging stations, but industry collaboration is making a huge impact. In 2023, a coalition of seven major automakers devised plans for a North American charging network featuring compatible ports, including the Combined Charging System (CCS) and the North American Charging Standard (NACS). During 2024, more automakers announced a shift to the NACS port. This regional standardization, coupled with public-private investment in a more robust charging market, will further support the adoption of EVs for consumers.

Progress is also being made in addressing interoperability challenges between EVs, charging stations and the grid. Around the world, joint initiatives between stakeholders, including electric utilities, regulators, OEMs and automakers, are working together to develop technology that fosters connection between disparate systems while supporting safety and performance and mitigating risks from cyber threats.

The standards ecosystem is also evolving, with the development of international and regional standards, including:

- UL 9741/CSA 348, the binational Standard for EV Power Export Equipment
- UL 1741, the Standard for Inverters, Converters, Controllers and Interconnection Systems Equipment for Use With Distributed Energy Resources

Together, these standards help drive energy transition and support smarter, safer reactive grid interconnection. While the U.S. automotive industry has historically been granted the ability to self-certify for automobile functionality, new crossover DER/EV standards and regulations require them to demonstrate compliance with these and other standards. That is typically done through third-party testing, inspection, assessment and certification.

UL 1741 Supplement SC for Bidirectional Electric Vehicle Supply Equipment (BEVSE)/Interconnection Systems Equipment (ISE) for EVs with Bidirectional Onboard Inverters is also being developed to facilitate a middle ground between the self-certified EV industry and the power generation infrastructure that requires National Electric Code® (NEC) and local grid code compliance with third-party Nationally Recognized Testing Laboratory (NRTL) oversight.

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> New smart inverters technology includes interoperability features that support remote control and fine-tuning capability that can be tailored for specific local grid conditions and needs of the utility. It is critical that all DERs include a common interoperability implementation to facilitate consistent DER control and adjustment to support the continual changes of the local grid. Interoperability can also facilitate DER updates to meet the future needs of the equipment and grid challenges.
>
> **Tim Zgonena**
>
> Principal engineer,
> Energy Resources Equipment and Systems

Milestones in energy transition

Global growth in renewable energy generation and storage

> "The International Energy Agency's (IEA) 2024 World Energy Investment report says total global energy investment this year will likely exceed $3 trillion for the first time, with $2 trillion spent on clean technologies such as renewables, electric vehicles and nuclear power."
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> — World Economic Forum[11]

EU investment in renewable power generation increased by 6% to $110 billion (USD).[6]

The Infrastructure Investment and Jobs Act allocated nearly $75 billion (USD) to clean energy, including $21.3 billion (USD) for grid improvement and expansion.[7]

In 2023, China's annual investment in power grids and storage reached $106 billion (USD).[8]

As of 2024, 46.3% of the India's total installed capacity included 200 GW of renewable energy.[9]

More than 85 million EVs (cars, buses and heavy trucks) are predicted to be in operation by the end of 2025.[10]

Standards spotlight

Cybersecurity certification for DERs and inverter-based resources (IBRs)

UL 2941, the Outline of Investigation (OOI) for Cybersecurity of Distributed Energy and Inverter-Based Resources, was published in April 2023. This OOI was developed in cooperation with the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) and includes testable requirements for energy storage and generation technologies, such as:

- Photovoltaic (PV) inverters
- EV chargers
- Wind turbines
- Fuel cells
- Other distributed energy resource technology

UL 2941 prioritizes cybersecurity enhancements for power systems featuring high-penetration, inverter-based resources, including renewable power production, and promotes designing cybersecurity features in new IBRs and DERs.

UL Solutions offers testing services for UL 2941 as a complement to testing for UL 1741, the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources.

Additional relevant standards for DERs

DERs are becoming more integral to the transition to a decarbonized future. As their importance grows, the standards ecosystem is also maturing due to the concerted efforts of stakeholders including code authorities, electric utilities, U.S. DOE National Laboratories, standards development organizations (SDOs), manufacturers, power producers and certification bodies.

Applicable standards vary based on product and usage type.

- UL 1741, the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
- IEC 62109 and UL 62109, the Standard for Safety of Power Converters for Use in Photovoltaic Power Systems
- IEEE 1547 and IEEE 2030 series of standards for Distributed Energy Resources Interconnection and Interoperability with the Electricity Grid
- UL 9540, the Standard for Energy Storage Systems and Equipment
- ANSI/CAN/UL 1973, the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Application
- CSA/ANSI FC 1:21/CSA C22.2 NO. 62282-3-100:21, Fuel Cell Technologies — Part 3-100: Stationary Fuel Cell Power Systems — Safety (Adopted IEC 62282-3-100:2019, second edition, 2019-02, with Canadian and U.S. deviations)

CONCLUSION

Building the future

DERs are reshaping power grids right now. Deployment of DERs — such as solar, wind, BESS, EVs and others — is steadily increasing and continues to reach new record highs across the globe. This continued growth is aligned with global decarbonization efforts and brings about many related benefits, such as reduced electricity costs, increased grid stability and resiliency directly related to locating advanced grid support power generation and storage within utility power distribution networks and where the energy is ultimately used.

The rise of DERs introduces many new challenges for all stakeholders involved in power grid and built environment management, from physical safety to cybersecurity risks. However, understanding the challenges, collaborating with other industry stakeholders, and taking a comprehensive approach to developing resilient, efficient systems that enable grid stability and reliability can help stakeholders overcome these challenges.

CONTACT US

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