Resilient Energy Platform

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Power Sector Resilience Technical Solutions

Photovoltaic technologies can be an integral part of diverse and resilient power system portfolios. *Photo by Dennis Schroeder, NREL 26962*

Background

Power sector vulnerabilities—weaknesses within infrastructure, systems, or operations—are susceptible to natural, technological, and human-caused threats. Impacts from these threats include:

- Power or water outages resulting from physical infrastructure damage or aging infrastructure
- Fuel supply, food, and water shortages
- Shifts in energy demand
- Ancillary financial, economic, and social implications of failures within systems.

In a world that relies increasingly on electricity services, addressing these vulnerabilities and building resilient power systems are critical to providing reliable and sustainable services, energy security, economic well-being, and quality of life.

As a critical first step to enable resilience and identify solutions, countries and localities can undertake power system vulnerability assessments that allow key stakeholders to determine where and under what conditions their systems may be vulnerable to natural threats—such as rising temperatures and sea levels, changing precipitation patterns, more frequent and severe episodes of extreme weather, and natural disasters—as well as human-caused threats, such as cyber-attacks and accidents. Based on this assessment, key technical solutions described in this fact sheet can be identified to enhance a site's resilience and, when replicated across a broader grid system, can enhance the power system as a whole. While traditional measures for resilient systems exist, including grid hardening (e.g., undergrounding of lines, strengthening transmission towers, etc.) this fact sheet includes emerging technical solutions. For detailed information on the power sector vulnerability assessment process and to learn from the experiences of other countries, visit: www.resilient-energy.org.

What is Power Sector Resilience?

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions to the power sector through adaptable and holistic planning and technical solutions (Hotchkiss et al. 2018).

Technical Solutions

Clean energy technical solutions can enhance resilience across the grid system to help provide more reliable and resilient power to end users. Several cutting-edge technologies and approaches are enabling countries to better prepare for and address threats to the power system. This fact sheet provides an overview of key technical solutions to support power sector resilience.

Diversifying energy generation sources

Resilient power systems often incorporate a diverse portfolio of electricity generation technologies to increase reliability and allow for service disruptions to be mitigated and resolved quickly (Cox et al. 2016). Resources can be diversified in relation to geography, fuel use needs, and water needs to support a more climate-resilient power system. As part of a portfolio-diversification strategy, renewable energy technologies can provide a power source that is harder to disrupt relative to traditional technologies. Relying on any one source of energy will create an unnecessary vulnerability to a power system. Utilizing appropriate renewable energy technologies and storage solutions and, in some cases, pairing those with fossil fuels, will not only enhance the resilience of a system through fuel diversification but will also reduce emissions associated with fossil fuel consumption. Solutions presented here are system-specific; power system planners and operators should undergo a vulnerability assessment and develop a resilience strategy that is specific to their vulnerabilities and needs.

Storage Supports Resilience in the Dominican Republic

During Hurricanes Irma and Maria in 2017, the Dominican Republic was able to utilize 20 MW of battery storage at two power plants to support grid stability, frequency control, and critical reliability services of the interconnected power system. Many island nations impacted by hurricanes are now planning to scale up deployment of microgrids, renewable energy, and storage systems to support resilience of the power system during future storm occurrences.

Microgrids and Renewable Energy in Rural Areas

Using renewable energy, battery systems, and islanding controls to create a microgrid in rural areas not only increases the resilience of a community or a facility, but also has the potential to meet rural electrification goals. Using microgrids with on-site renewable energy to supply backup power during grid outages will alleviate the need for fossil fuels when fuel supply chains may be disrupted, particularly in rural areas that may be more challenging to resupply during large-scale disruptive events.

Photo from iStock 453305585

Distributed generation

Decentralizing energy sources is a technique used to enhance power system resilience. On-site renewable energy generation (or other generators) can reduce the disruption to a site of a grid outage, mitigating the impacts of a long-term outage. Microgrids are often implemented where on-site renewable energy is combined with energy storage to support resilience. Systems that are designed to operate in islanded mode can be isolated from a larger grid, allowing the system to generate and distribute energy on-site in the event of a power outage. The capability of microgrids to operate in islanded mode can be critical in supporting resilience by providing a backup resource during a grid outage while also allowing certain loads to be covered as linemen secure the larger grid. An additional benefit of microgrids is they can be designed to provide power to critical loads, such as health care facilities, during a grid outage.

Energy storage

Integrating storage into electricity grid systems can help smooth variation in renewable energy sources, such as wind and solar generation, while adding redundancy to the grid in the event of power outages. When distributed systems with battery storage are connected to the larger grid, they can be designed, through interconnection agreements with a utility provider, to include islanding controls and energy storage to allow for grid disconnection that enables operation behind the meter, without back-feeding power to the larger grid. This configuration allows for independent operation during grid outages and the provision of low-emission power when the grid is operating normally or when the grid is down. While the most common energy storage technologies are batteries, other storage methods may include flywheels, compressed air energy storage, and pumped hydro storage. While energy storage is a key component of microgrids, it's important to consider whether storage solutions can enhance resilience on the larger grid as a whole. Incorporating well-designed battery storage, for example, at the residential scale, can enhance resilience across the grid system to help provide more reliable and resilient power to end users.

Utility-scale energy storage can be an important component of renewable energy integration for resilience and improves stability and reliability, allowing for response and recovery to a disaster in different ways than a conventional system. While distributed or microgrid renewable energy systems can be incorporated without energy storage, adding the flexibility of energy storage technologies may allow microgrids or critical loads to operate for longer periods of time without grid connection.

Demand-side management and efficiency

Demand-side energy management is often overlooked in power sector resilience strategies; however, this technical solution can support both short- and long-term goals. Energy demand management, also known as demand-side management or demand-side response, is the modification of consumer energy use through education and behavior change; energy efficiency measures; and financing incentives, such as utility tariff structuring. During short-term extreme events, demand-side management can reduce peak loads as well as the need for increased generation over time. This technique can reduce the loads needed to be met by on-site generation or battery storage capacity. Good utility-scale demand-side management and approaches, such as improved energy efficient building codes, can support a more resilient power system.

Interconnected Smart Grids and Meteorological Information

Real-time weather data, along with smart-grid controls, can help with fault detection as well as support the incorporation of higher penetrations of renewable energy generation sources with variable energy. Meteorological data can help with load predictions on grid systems and enable base load control with variability from technologies such as hydro, solar, and wind. Additionally, smart-grid controls can be used to segregate circuits and communicate with various feeders. Redirecting loads during major grid outages, or allowing distributed renewable systems to operate in islanded mode, can reduce the impacts of grid outages.

Smart grids

A smart grid provides two-way communication and flexible control within an electricity network to support flexibility, efficiency, and resilience. In many ways, smart grids can bring together all of the technical solutions highlighted above under a more resilient electricity system. Through automation technology, technologies or devices within a smart grid collect data in real time that can be analyzed by utilities and system operators. Grid technologies, or "nodes," can then be controlled and altered based on the data received and analysis of the situation. In the context of climate resilience, smart grids can support several positive outcomes. For example, because of real-time communication on changing needs and circumstances associated with extreme climate-related events (e.g., storms and other disasters), responses and decisions regarding new power needs and power diversion can be made quickly. If a generation source is impacted by a storm, other generation sources can be accessed more quickly, and power can also be diverted to critical facilities, such as hospitals. Smart meters can allow for this type of responsiveness by sending data directly from electricity meters to energy providers, and can enable islandable systems to support resilience during disasters or grid outages. Additionally, reducing peak loads can lessen system instability and stress during extreme events and can reduce the need for increased electricity supply over time. With any smart-grid control system, it is important to factor in cybersecurity measures to ensure secure communication between devices.

Relocating or fortifying vulnerable assets

Understanding where the most at-risk assets exist within the power system will help with activities such as relocating assets above flood levels and away from potential high-risk areas, such as along coastlines (moving inland and upland), or burying underground aerial lines that are at risk from high winds or that serve the most critical facilities (e.g., medical centers or emergency shelters).

Resilient Energy Platform

The Resilient Energy Platform helps countries and localities address power system vulnerabilities by providing strategic resources and direct country support to enable planning and deployment of resilient energy solutions. This includes expertly curated reference material, training materials, data, tools, and direct technical assistance in planning resilient, sustainable, and secure power systems. Ultimately, these resources enable decision makers to assess power sector vulnerabilities, identify resilience solutions, and make informed decisions to enhance energy sector resilience at all scales, including local, regional, and national scales. To learn more about the technical solutions highlighted in this fact sheet, visit the Resilient Energy Platform website at: www.resilient-energy.org.

References and Resources to Learn More

Brown, Ray, Guillaume Prudent-Richard, and Katrina O'Mara. "Enhancing Power Sector Resilience: Emerging Practices to Manage Weather and Geological Risks." World Bank. Washington, D.C. June 2016. https://openknowledge.worldbank.org/handle/10986/26382

Clean Energy Group. "Resilient Power—A Project of Clean Energy Group." Seth Mullendore, project director. https://www.cleanegroup.org/ceg-projects/resilient-power-project/

Cox, Sadie, Eliza Hotchkiss, Dan Bilello, Andrea Watson, Alison Holm, National Renewable Energy Laboratory (NREL); and Jennifer Leisch, U.S. Agency for International Development (USAID). "Bridging Climate Change Resilience and Mitigation in the Electricity Sector Through Renewable Energy and Energy Efficiency—Emerging Climate Change and Development Topics for Energy Sector Transformation." NREL/TP-6A20-67040. November 2017. https://www.nrel.gov/docs/fy18osti/67040.pdf

Cox, Sadie, Pieter Gagnon, Sherry Stout, Owen Zinaman, Andrea Watson, and Eliza Hotchkiss, NREL. "Distributed Generation to Support Development-Focused Climate Action—Emerging Climate Change and Development Topics for Energy Sector Transformation: An EC-LEDS White Paper Series." NREL/TP-6A20-66597. September 2016. https://www.nrel.gov/docs/fy16osti/66597.pdf

Field, C. B., V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, and P. M. Midgely [Editors]. "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation—A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change." Cambridge University Press. Cambridge, United Kingdom, and New York, NY. 2012. https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/

Hotchkiss, Eliza, Alex Dane, and Connie Komomua. "Resilience Roadmap." National Renewable Energy Laboratory (NREL), 2018. https://www.nrel.gov/resilience-planning-roadmap/

Queensland Reconstruction Authority. "Planning for Stronger, More Resilient Electrical Infrastructure—Improving the Resilience of Electrical Infrastructure During Flooding and Cyclones." 2011. https://www.statedevelopment.qld.gov.au/resources/guideline/qra/planning-resilient-electrical-infrastructure.pdf

U.S. Department of Energy (DOE). "U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather." Washington, D.C. 2013. https://www.energy.gov/downloads/us-energy-sector-vulnerabilities-climate-change-and-extreme-weather-

Wang, Xiaoping, Ray Brown, Guillaume Prudent-Richard, and Katrina O'Mara. "Enhancing Power Sector Resilience Emerging Practices to Manage Weather and Geological Risks." The World Bank, 2016. http://documents.worldbank.org/curated/en/469681490855955624/pdf/113894-ESMAP-PUBLIC-FINALEnhancingPowerSectorResilienceMar.pdf

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The USAID-NREL Partnership addresses critical challenges to scaling up advanced energy systems through global tools and technical assistance, including the Renewable Energy Data Explorer, Greening the Grid, the International Jobs and Economic Development Impacts tool, and the Resilient Energy Platform. More information can be found at: **www.nrel.gov/usaid-partnership**.