4 Sources of Flexibility in Electricity Systems - System Operations

KEY LEARNING POINTS:

- Changes to electricity system operational practices are among the lowest-cost options to improve flexibility
- The particular operational mechanisms available depend on the size, market structure, and other characteristics of the electricity system
- Operational mechanisms may require significant changes to institutional mechanisms and practices

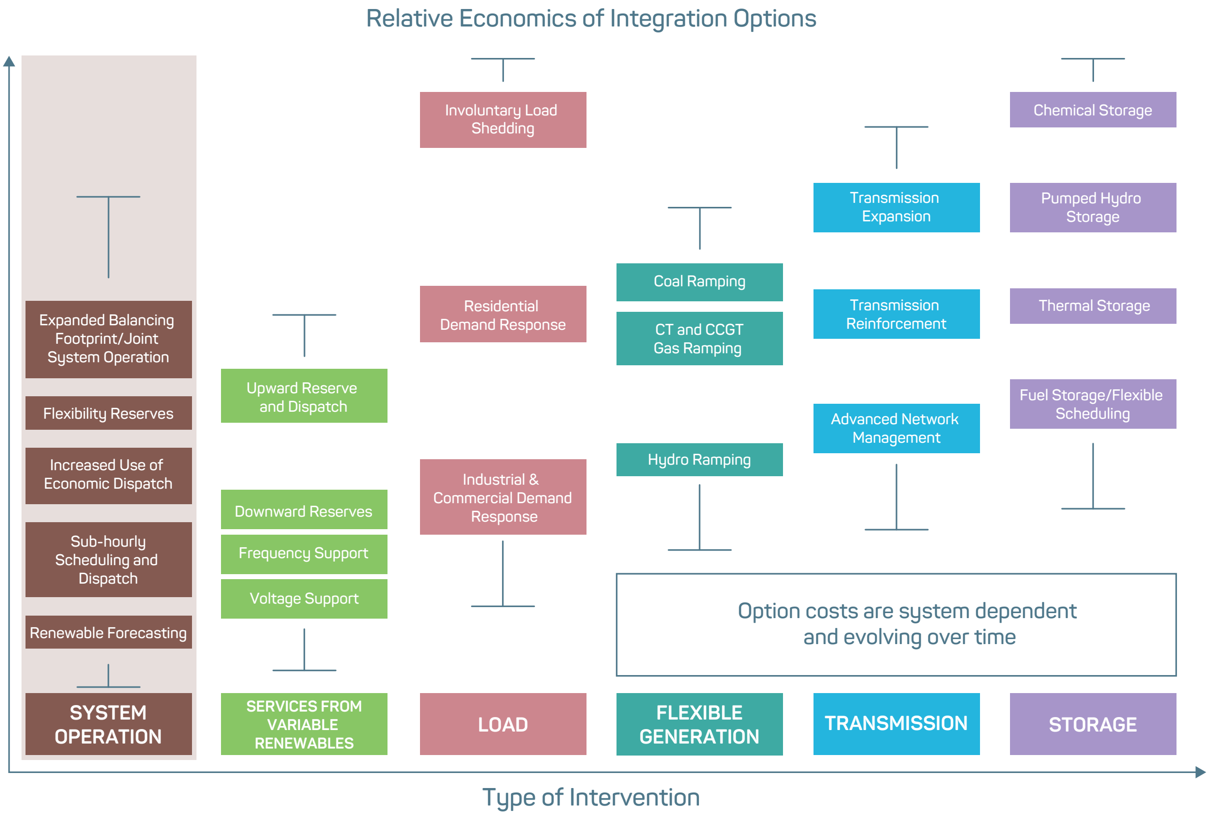

Figure 1: Flexibility refers to the ability of an electricity system to respond to changes in electricity demand and generation and is an important characteristic of electricity systems with growing levels of variable renewable electricity. Example options—and their relative costs—for enhancing electricity system flexibility are illustrated above. This short note focuses on the system operations category. Source: Cochran et al. (2014). *Flexibility in 21st Century Power Systems.*

Changes to electricity system operational practices are among the lowest-cost options to improve flexibility.

The flexibility of a particular electricity system is in part governed by its physical components, including the composition of its generation fleet, extent of transmission networks and interconnections, and availability of energy storage. While modifying these physical assets (for example, by adding flexible natural gas generation, battery storage, or new transmission) can enhance flexibility, new or retrofitted physical infrastructure typically requires significant capital investments. A lower-cost strategy—especially to manage low- to moderate penetrations of variable renewable electricity on the grid—is to change system operational practices to extract as much flexibility as possible from the existing physical electricity system.

Depending on the size, market structure, and other characteristics of the electricity system, system operators can draw upon a suite of operational mechanisms to enhance flexibility and cost-effectively integrate variable renewable electricity.

Examples include the following:

- *Implementing solar and wind power forecasting.* State-of-the-art methods enable electricity system operators to use solar and wind power forecasts (which range from minutes-ahead to days-ahead of real-time, as shown in Figure 2) to reduce uncertainty, improve scheduling and economic (i.e., merit order) dispatch, and reduce the need for reserves.
- *Increasing the speed of electricity system operations*, for example, by moving from hourly to sub-hourly (5-30 minute) dispatch periods, updating schedules (unit commitment) multiple times throughout the day, and implementing sub-hourly interchange schedules. Fast operations (and, where applicable, markets) allow operators to make decisions closer to real time, taking into consideration the best-available forecasts for both variable renewable electricity output and electricity demand. These practices reduce the need for expensive reserves and allow more accurate and efficient operation—regardless of the penetration level of solar and wind.

- *Incorporating variable renewable electricity into economic dispatch (i.e. the merit order)* instead of implementing "must-take" or "priority dispatch" for these resources. Since solar and wind generators have very low marginal costs, they will usually be dispatched first according to the merit order; however, economic dispatch provides the system operator the flexibility to strategically and economically curtail variable renewable electricity (i.e. reduce generator output from what they could otherwise produce given available resources) in relatively rare instances when, for example, doing so is less expensive to the system than shutting down and then restarting a conventional generator to accommodate a short-term spike in solar or wind output. In addition to dispatch procedures, revisions to contracts and/or market design may be required to incorporate variable renewable electricity into economic dispatch while maintaining investor certainty in revenue generation.

- *Incorporating flexibility reserves* into an electricity system's ancillary services procurement plan, e.g. by compensating generators based on fast ramping capabilities.

- *Expanding the balancing area footprint* (e.g. by enhancing cooperation with neighboring electricity systems). Larger and more geographically diverse balancing areas smooth the variability of solar and wind output because weather and demand patterns will vary across a large system; thus, increases in solar or wind output in one part of the system may be offset by decreases in others.

- *Flexible operation of conventional and renewable electricity generators.* This topic is covered in further detail in a separate note.

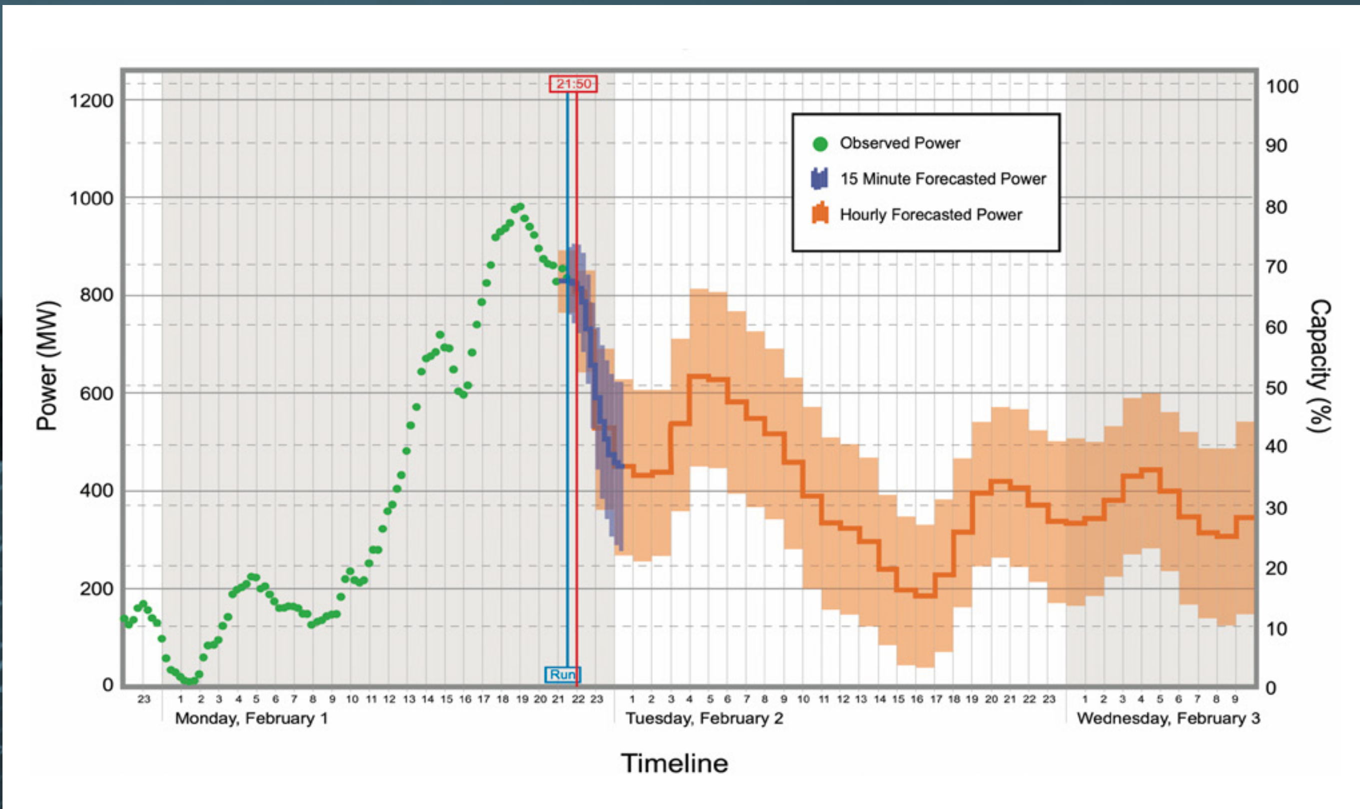

Figure 2: This graphic shows a sample hourly and 15-minute wind forecasting output for Xcel Energy, a utility in the United States that meets approximately 15% of annual demand with wind power. Green dots indicate the actual wind power generation up to the forecast point (12:50 on February 1); the solid purple and orange lines shows the predicted wind power output; and the shaded area shows the typical forecast error. Source: Tian and Chernyakhoviskiy. (2016). *Forecasting Wind and Solar Generation: Improving System Operations.*

While operational mechanisms have relatively low capital costs compared to other flexibility measures, they may require significant changes to institutional mechanisms and practices.

The specific approaches to improving system operations to access flexibility depend on institutional contexts, including the relative roles of the system operator, wholesale electricity market and/or administrative decisions by a vertically integrated utility. For example, implementing flexibility reserves could involve defining new ancillary market products in the former case, or revising contracts to include compensation for flexibility capabilities in the latter.

In many electricity systems, operational measures alone can address renewable electricity integration challenges that arise at low to moderate penetration levels.

For example, studies have found that the electricity systems in the United States can achieve 30% or higher solar and wind electricity penetration on an annual basis primarily through the implementation of operational measures, including solar and wind forecasting, increases to the size of the geographic area over which solar and wind resources are accessed, sub-hourly scheduling, and better utilization of existing transmission capacity [1, 2].

Similarly, a recent study of India's electricity system indicates that coordinating operations across states will help the country meet its goal of deploying 160 GW of solar and wind capacity and save USD 980 million annually relative to operating the system on a state-specific basis [3]. In Europe, recent research finds that changes to balancing market operation have reduced costs in Germany and Britain despite substantial increases in the shares of wind and solar electricity [4].

References

[1] GE, (2010), Western Wind and Solar Integration Study. NREL/SR-550-47434.

[2] Bloom et al., (2016), Eastern Renewable Generation Integration Study. NREL/TP-6A20-64472.

[3] USAID and Ministry of Power, India (2017), Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study

[4] Joos, M. and Staffell, I., (2018) Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany, Renewable and Sustainable Energy Reviews, (86), 45-65

For additional reading, please visit http://greeningthegrid.org, which provides curated resource libraries on several topics discussed in this note, including system operations, ancillary services, balancing area coordination, and forecasting.

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