BALANCING POWER SYSTEMS WITH LARGE SHARES OF WIND AND SOLAR ENERGY

Power system operation includes balancing supply and demand at each instant. Wind and solar energy increase uncertainty and variability in the system and thus balancing needs. Balancing is done by adjusting output levels of some of the power plants, by charging and discharging storage, or by adjusting demand via market signals to increase or decrease electricity usage. Just like the other options, wind and solar power plants can also be used to provide balancing.

How are power systems balanced?

Power is usually scheduled one day ahead. The scheduling process provides sufficient capacity to meet the demand at each hour, or even at shorter intervals like 30 or 15 minutes. This means having enough generation and flexibility options online to balance supply and demand. The output levels of power plants can still be fine-tuned close to real-time when there is more accurate information available.

When generation and demand are in balance, the frequency of the power system is close to the nominal frequency (50 or 60 Hz). When generation is higher or lower than demand, the frequency will start to increase or decrease. Bringing it back to normal is important to keep the entire system functioning. Thus, sufficient flexibility—the ability to change the output level of generation, demand or storage—needs to be available to balance the demand and supply and maintain frequency, even in time frames of seconds and minutes.

Power systems are balanced at the system level. This means that minute-to-minute variability and uncertainty are combined, from all the consumers, and all power plants, including wind and solar. Only the aggregate system imbalances between demand and generation are corrected by using balancing power.

The real-time balance during the operating hour is maintained by operating reserves. Traditionally, reserves are provided by those conventional power plants which are able to adjust their output level quickly in response to balancing needs (Figure 1). Recently, balancing has increasingly been done through the participation of demand, storage, as well as wind and solar power plants.

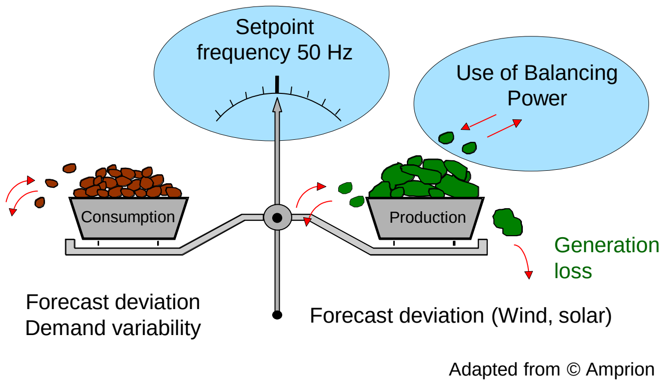

Figure 1. *Maintaining the frequency of the power system means balancing generation and demand in real time.*

How to manage variability and forecast errors in wind and solar energy?

Adding wind and solar energy will impact the scheduling and operation of other power plants as well as the operating reserve (Figure 2).

Higher or lower wind and solar generation is usually seen day ahead in the generation forecasts. This will impact how much other generation is scheduled.

Intraday markets allow forecast errors to be managed after the day-ahead markets have closed. Remaining variations and forecast errors will be handled by operating reserves in real time. The reserves will be called upon based on total system imbalances (Figure 3). Variations of demand, wind and solar generation often cancel each other out, and at other times more reserves will need to be activated to balance the system.

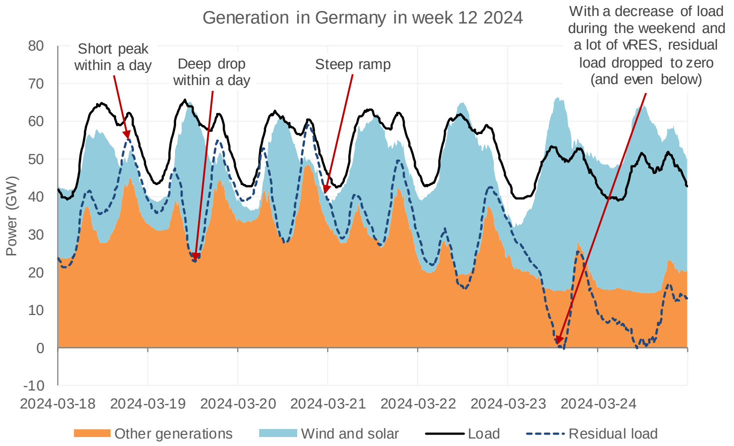

Figure 2. *Example of how wind and solar can change within a week and even a day, leading to a residual load varying from load to negative value. (Source: data from Energy-Charts).*

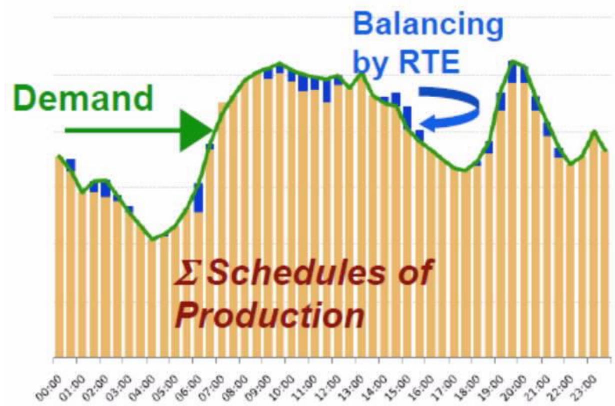

Figure 3. *Scheduling the generation units to cover the anticipated demand is usually made day-ahead. Dispatch can be fine-tuned closer to real time. During the operating hour, balancing (operating reserves) are used to maintain the balance. (Source: RTE, the transmission system operator of France).*

How to make sure there is enough flexibility to balance power systems with a large share of wind and solar energy?

Often there is more flexibility available in the existing generating units than is used today, both day-ahead and real-time. However, increasing flexibility will be an important consideration when anticipating larger shares of wind and solar energy in a power system.

Increased flexibility can decrease the operational costs of the power system since there are more options available for balancing. Flexibility can be shared with neighbouring regions using transmission interconnections (trading electricity between areas). Wind and solar power plants can offer fast responses when other options are more expensive. Curtailment of wind and solar can, in some instances, be cost effective and support flexibility because it allows wind and solar to provide upward reserves. Flexibility can also be provided by storage. Another source of flexibility is offered by the consumer side; this is called demand response.

Electrification of other energy sectors, like transport and heating, will bring new demand types that may have more flexibility than today's electricity consumption. Decarbonisation of industry sectors (e.g. steel, feedstock) increases the use of electrolysis, which can also contribute to flexibility options if used intelligently.

Flexibility is affected by operational practices. For example, balancing needs can be reduced by using gate closure times that are closer to the physical delivery of electricity, increasing the time resolution of the markets via shorter dispatch intervals, and providing updated demand and generation forecasts closer to real-time. In general, operating larger balancing areas helps systems accommodate more wind and solar power by reducing total variability and pooling more sources of flexibility.

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- IEA (2019). **Status of Power System Transformation 2019: Power system flexibility**. https://www.iea.org/reports/status-of-power-system-transformation-2019
- Greening the Grid (2015). **Sources of operational flexibility**. Fact sheet available at https://greeningthegrid.org/Grid-Integration-Toolkit
- 21st Century Power Partnership (2014). **Flexibility in 21st Century Power Systems**. http://www.21stcenturypower.org/publications.cfm

More information

This Fact Sheet draws from the work of IEA Wind TCP Task 25, a research collaboration among 17 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind TCP Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at

https://iea-wind.org/task25/

See also other fact sheets

Flexibility for Power Systems
Storage for Power Systems
How Do We Ensure Long-Term Reliability of Future Power Systems?
Variability and Predictability of Large-Scale Wind Power
Flexibility Through Electrification
Impact of Wind and Solar on Transmission Upgrade Needs
Wind and Solar Energy Curtailment
Wind and Solar Integration Issues