FLEXIBILITY FOR POWER SYSTEMS

Flexibility is the ability of a power system to manage variability of demand and generation. Flexibility includes power regulation and operational reserves, which have historically depended on thermal power plants. On top of dispatchable power generators, there are new sources of flexibility increasingly used, like energy storage, interconnectors and demand side management. The optimal combination of flexibility is a key issue for grid operation under large amounts of wind and solar.

What is flexibility?

Traditionally, intra-hour, hourly, daily, weekly, seasonal, and inter-annual variations in demand have been mainly managed by conventional power plants.

The ability and commitment of a power plant to regulate its power output has been called regulating power, balancing power or reserve, and various types of these products with different time scales are prepared, so that they can be activated in seconds, minutes, or hours.

Today, a broader concept of flexibility is increasingly applied by grid operators to accommodate larger amounts of wind and solar.

The term “flexibility” is simply defined as “the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales” (IEA 2018).

Who can provide flexibility?

Flexibility can be provided from many grid elements, by larger or (aggregated) smaller power plants, storage systems, and demand side resources, depending on the time scale (Figure 1).

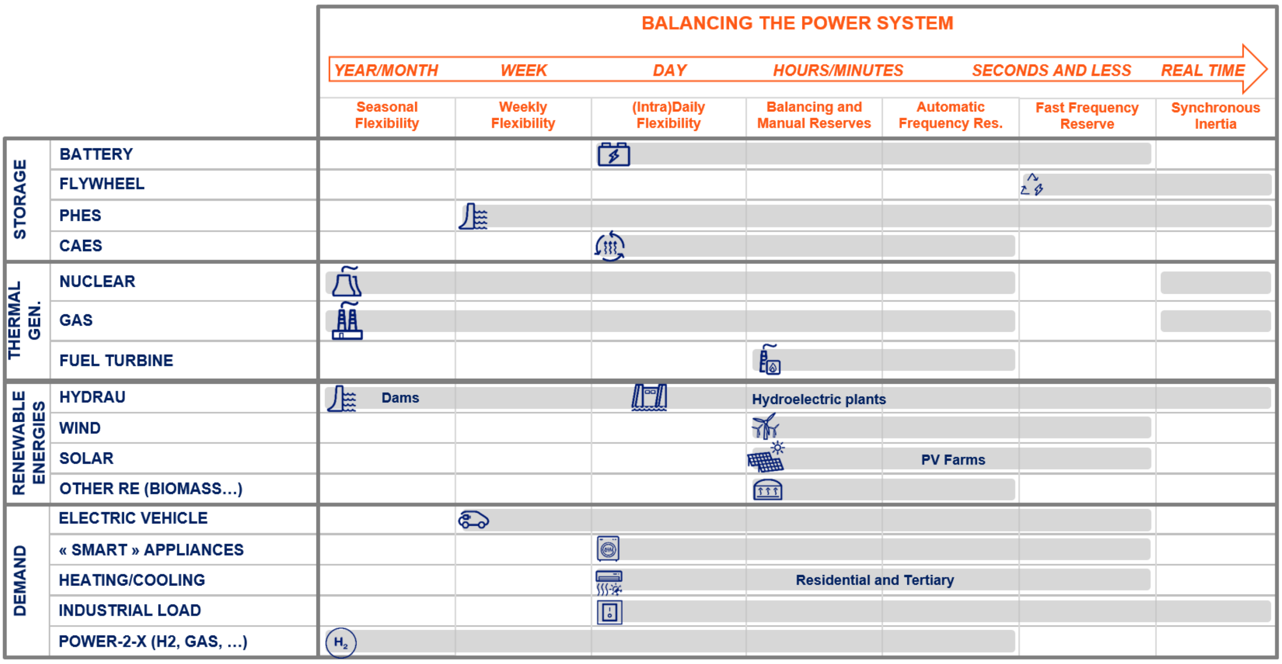

Figure 1. *Flexibility solutions at various time scales. (Source: EDF).*

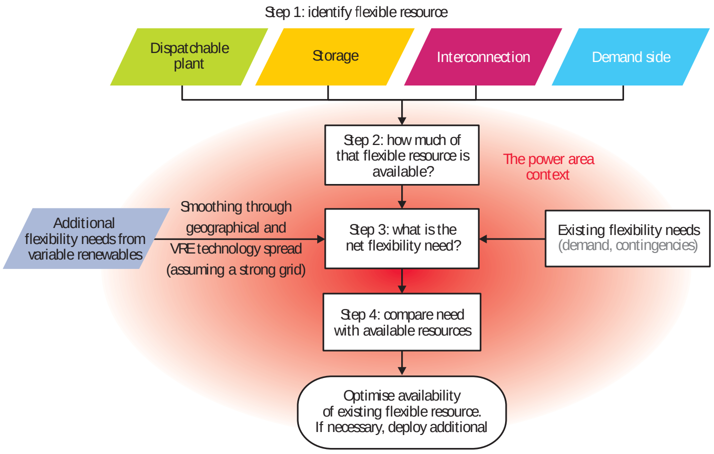

Figure 2. *Flexibility Assessment Method proposed by IEA. (Source: IEA, 2011).*

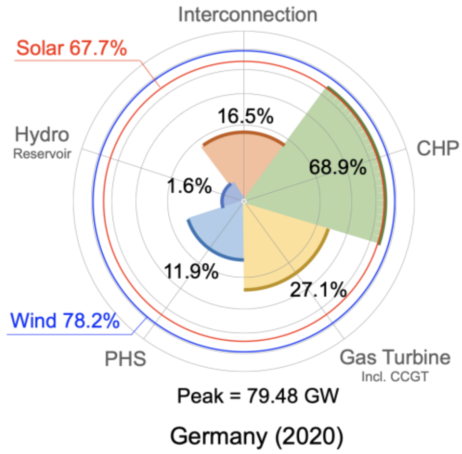

Figure 3. *An example of flexibility chart: German flexibility resources in 2020. (Source: Yasuda et al., 2023).*

Flexibility sources can be divided into 4 types (Figure 2):

- **Dispatchable plant:** Hydropower plant with reservoir, bio-fuelled combined heat and power plant, gas-fired power plant, etc. A part of wind and solar can also be considered dispatchable.
- **Storage:** Hot water storage, pumped hydro storage, flywheel, battery energy storage system, etc.
- **Interconnection:** Sharing flexibility resources via interconnectors will mutually enhance flexibility in both areas. HVDC (High Voltage Direct Current) links can also provide flexibility by themselves.
- **Demand side:** Autonomous or remote control of demand side equipment can provide flexibility. Industrial processes also have significant potential for flexibility provision.

Flexibility strongly relates to the concept of sector coupling. Flexibility can be provided from the heating sector (hot-water storage and heat pumps), the transport sector (electric vehicle charging), and the industrial sector (new electric loads combined with storage buffers as well as power-to-X solutions like hydrogen derivatives).

How can the flexibility potential be assessed?

Flexibility assessment tools have been proposed by several researchers and international organisations. A simple, easy-to-understand and at-a-glance tool is Flexibility Chart developed by IEA Wind Task 25 (Yasuda et al., 2023).

The standard Flexibility Chart contains five axes that represent the proportion of selected flexibility sources (interconnector, combined heat and power, gas turbine, pumped hydro storage and reservoir hydro) relative to the peak demand in the given country or area. As these statistical data are easily available in many countries, the tool can be used even by non-experts. A further sixth axis of battery can be added if reliable statistical data is available.

Figure 3 shows an example of the Flexibility Chart, where the potential of flexibility resources in Germany is visually illustrated. Although it is often thought that Germany can accommodate renewables because of rich interconnection capacity, the Flexibility Chart shows that combined heat and power capacity can contribute more flexibility to a high share of VRE.

An example of a more detailed flexibility assessment tool is IRENA FlexTool (IRENA 2018).

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 (2018). **Status of Power System Transformation 2018**. https://www.iea.org/reports/status-of-power-system-transformation-2018
- IEA (2011). **Harnessing Variable Renewables**. https://www.iea.org/reports/harnessing-variable-renewables
- IRENA (2018). **Power System Flexibility for the Energy Transition, Part 1: Overview for Policy Makers**. https://www.irena.org/publications/2018/Nov/Power-system-flexibility-for-the-energy-transition
- Yasuda, Y. et al. (2023) **Flexibility chart 2.0: An accessible visual tool to evaluate flexibility resources in power systems**. Renewable and Sustainable Energy Reviews, 174 (2023) 113116. https://doi.org/10.1016/j.rser.2022.113116

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

Balancing Power Systems with Large Shares of Wind and Solar Energy
Storage for Power Systems
Flexibility Through Electrification
Impact of Wind and Solar on Transmission Upgrade Needs
Wind and Solar Integration Issues