What limits for VRES integration in grids?

What limits to the Integration of Variable and Intermittent Renewable Energies into Electricity Grids and consequences?

A study by Georges Sapy – Translated into English by Elisabeth Huffer – May 2024

Renewable energies (RES) from wind and sun are not stock energies, but flow energies (linked to wind speeds and solar radiation respectively) that have two characteristics unsuited to the satisfaction of human needs for low-carbon electricity, specifically:

* They are variable and intermittent, subject to weather conditions and day-night cycles. As a result, their transformation into electrical energy produces "non-dispatchable" electrical power, which has very little correlation with human consumption requirements: **these energies are incapable of meeting alone the electricity needs of developed societies, they have to be supplemented with "dispatchable" means**: generation means based on stock energies (hydro, nuclear or fossil, etc. sources); energy storage/de-storage means; load shedding/controlled demand deferral.

* They are thinly distributed spatially so that they require extensive surfaces to produce the large quantities of energy needed in developed countries. **They cannot, consequently, produce enough electricity to supply countries which combine limited land and/or sea territories and a large population.** A comparison of Norway and Germany is illuminating in this respect: the two countries have areas of the same order of magnitude (≈ 322,000 and ≈ 357,000 km² respectively) but very different populations (≈ 5.5 and ≈ 84 million inhabitants respectively: ≈ 15 times as much for Germany). Furthermore, Norway produces ≈ 95% of its electricity from hydropower, Germany ≈ 5%: it has realized that it will never be able to produce the remaining ≈ 95% from wind and solar. As a result, it plans to rely on massive imports of low-carbon hydrogen over the coming decades in order to decarbonate its economy.

* **But there is a third constraint that "overshadows" the previous two**: the massive use of wind energy (via wind turbines) and solar energy (via photovoltaic panels) entails a major technological change in the way power grids operate. These means of production are not coupled to the grid via synchronous machines (alternators), as are the dispatchable means of production, but via electronics technologies (power electronic inverters) which follow very different physics laws. **Network operation thus depends on the penetration ratio of wind and/or photovoltaic electricity**:

- As long as this ratio is moderate, the grid remains driven by alternators, synchronous machines which have the extremely interesting property of being able to operate naturally "as a network", i.e. together in a perfectly synchronous manner, "forming" the grid on their own;

- **When this ratio becomes very large, and there are no longer enough synchronous machines to naturally "form" the grid, there is a complete paradigm shift: the laws of physics that currently govern grids no longer apply.** Hence the major question: can power electronic inverters in turn "form" the grid as stably, resiliently, and reliably as synchronous machines, on the basis of their electronic and digital technologies? **The answer to this question is crucial for the operational viability of a grid with a very large penetration ratio (close to 100%) of electricity from wind and/or photovoltaic sources.**

Well, the answer today is totally uncertain: no one can to date assert with proven certainty, validated by experience on real grids, that such operation is viable. The strategic consequences of this uncertainty are major for the future of power systems with very high levels of wind and/or photovoltaic electricity, given the very long-time frame required to adapt power systems (several decades): 2050 must be thought through now.

The present study focuses mainly on this last issue, while the first two are also addressed. It comprises an "executive summary" and a detailed "supporting study".

Link to Georges Sapy's study : What limits for VRES integration in grids?