iea wind

Task 25 Design and Operation of Energy Systems with Large Amounts of Variable Generation

Fact Sheet

IMPACTS OF WIND (AND SOLAR) POWER ON POWER SYSTEM STABILITY

As electrical grids integrate higher shares of wind and solar power, assessing their impact on power system dynamics becomes increasingly important. Blackouts are very costly for society, so system reliability must be maintained at a very high level. There is increasing operational experience that wind and solar power plants can support the system during disturbance conditions, if the latest technology is adopted, suitable planning has been undertaken, and appropriate incentives are in place.

How are power system disturbances and blackouts traditionally managed?

System operators must continuously monitor the stability of their system (Figure 1), and maintain its robustness to disturbances. Strategies must be devised to minimise the effect of potential unforeseen events, e.g. sudden power plant failure or disconnection of an overhead line.

During fault conditions the system response should be assessed on the timescale of fractions of a second. A number of stability issues need to be prepared for, depending on whether the demand is high or low, which generators are on-line, as well as the network topology.

How can wind (and solar) power affect and support power system stability?

Wind (and solar) power are not a likely cause of system disturbances. However, their associated variability and uncertainty can further complicate situations caused by faults. Disturbances can be mitigated through adapting operational practices, with the support of responses from wind (and solar) plants. Such responses can be enforced through grid connection rules, called grid codes. They can also be incentivised, being paid for through system services.

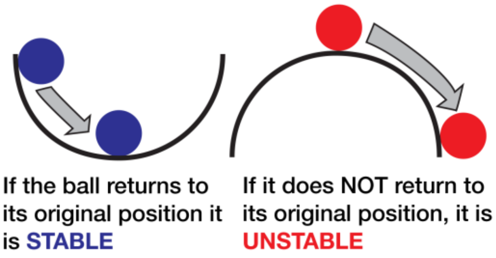

Figure 1. *Stable vs. unstable system (Source: Kundur et al., 2004).*

The nature of wind (and solar) grid support, for the four main types of stability, is listed:

- *Voltage stability*: Modern wind turbines and solar PV panels can support their local voltage by controlling their reactive power output, assuming the design of suitable controls.
- *Transient stability*: A network fault, e.g. a tree branch short circuiting an overhead line, may result in the flow of large (damaging) currents. Modern large-scale wind and solar power plants must ‘ride-through’ most such conditions. Moreover, they can enhance system stability by injecting reactive current and supporting their local voltage, as required.
- *Small-signal stability*: Single generators, or groups of generators, may slowly oscillate against each other for a period of seconds to minutes following a small disturbance. Wind and solar power plants are unlikely to initiate or contribute to such oscillations, but their presence can alter the number and location of online conventional generators, and, hence, the ability to dampen such oscillations. Wind and solar plants can support oscillation damping through appropriate control.
- *Frequency stability*: If an online generator suddenly trips off, the system frequency will quickly start to fall. If the frequency can’t be restored within several seconds there is a danger of system collapse and a blackout. Frequency stability can be more challenging for smaller systems, especially when the instantaneous wind (and solar) share of generation is more than 50% of the system demand. This is not yet a problem for larger systems. Modern wind turbines, due to the mass

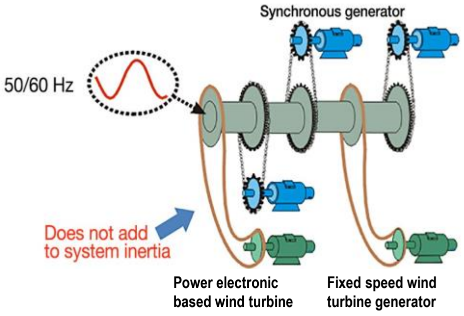

Figure 2. *Synchronous power system – operates at close to a constant frequency (50 or 60 Hz). Conventional generators, due to their rotating masses, provide inertial support and tend to keep the frequency constant. Most modern wind turbines, and also solar power plants and battery storage, are connected through power electronics and will not naturally provide an inertial response.*

of their rotating blades, possess a large stored rotational energy. With suitable controls, some of this stored energy can be temporarily released to provide what is known as a fast frequency response. Wind (and solar) generation can also provide a governor-like response, if suitably curtailed beforehand, as an additional measure to improve frequency stability.

If the worst does indeed happen and a disturbance results in the blackout of an entire power system, then generators with blackstart capability are required to restart the system. Wind (and solar) generation have not traditionally been associated with such a role.

What open issues exist for wind (and solar) power contributing to system stability?

Wind (and solar) power plants have been demonstrated in simulation studies, practical tests and real-world implementations to improve the stability of a well-designed system. They can provide a fast power response to aid frequency stability, a reactive power response to support the voltage during steady-state and fault conditions, and inject active and/or reactive power to dampen system oscillations, etc.

Such capabilities are increasingly applied, as the wind (and solar) share are sufficiently high that responses from wind (and solar) generation are required. Some examples are Hydro Quebec, ERCOT and Ireland, where wind (and solar) generation actively participate in the provision of frequency and voltage support services.

As some systems transition towards net zero carbon emissions, renewables only operation, and, indeed, only power electronic based renewables, such as wind and solar, is of increasing interest. Existing wind and solar plants are designed to “follow” the grid, which has traditionally been “formed” by conventional generators. Hence, a 100% renewables system likely requires that some wind and solar plants possess “grid forming” capability, an area of active study. A 100% renewables system also requires that some generation possess blackstart capability, again an active area of study, involving grid forming capability, local energy storage and network locational challenges.

The Irish power system has been studied in detail for current and (potential) future stability issues. Ireland is a small-sized island system where there are fewer large rotating masses to provide inertia to resist changes to the system frequency. Hence, all changes occur more quickly, even without wind power being present (Figure 2). In 2019, Ireland experienced up to 84% contribution from wind generation at certain times, with an annual average wind energy share of ≈32%. A 70% renewables share is targeted for 2030, implying many more time periods with very high wind (and also solar) power shares. To reach these higher shares in the future, special measures are being undertaken, including new system support services, strengthening of the existing transmission network, advanced system operator support tools, and enhanced performance monitoring of all generation plants.

Associated publications

- ESIG Guide on Grid Reliability Under High Levels of Renewables https://www.esig.energy/reports-briefs/
- ESIG (2019). **Toward 100% Renewable Energy Pathways: Key Research Needs** https://www.esig.energy/reports-briefs/
- Flynn, D., et al. (2017). **Technical impacts of high penetration levels of wind power on power system stability**. Wiley Interdisciplinary Reviews: Energy & Environment, 6, e216.
- Holttinen, H. et al. (2019). **Design and operation of power systems with large amounts of wind power**. Final summary report, IEA WIND Task 25, Phase four 2015–2017. https://community.ieawind.org/task25/ourlibrary
- Hodge, B.M., et al. (2020). **Toward 100% variable inverter-based renewable energy power systems**. Wiley Interdisciplinary Reviews: Energy & Environment
- Kundur, P., et al. (2004). **Definition and classification of power system stability**. IEEE Trans. PWRS, 19(3), 1387–1401.
- Miller, N., et al. (2014). **Western Wind and Solar Integration Study Phase 3 – Frequency Response and Transient Stability**. https://www.nrel.gov/grid/wwsis.html

More information

This Fact Sheet draws from the work of IEA Wind Task 25, a research collaboration among 18 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 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://community.ieawind.org/task25

See also other fact sheets

Transmission Adequacy with Wind Power Fact Sheet
Balancing Power Systems with Wind Power Fact Sheet
Wind Integration Issues Fact Sheet