Inertia and the Power Grid: A Guide Without the Spin

The power grid is evolving to include ever-higher levels of solar and wind—which don't provide inertia. Should system planners and operators panic? No. Here's why.

Photo from iStock 1069774530

What Is Grid Inertia?

Inertia in power systems refers to the energy stored in large rotating generators and some industrial motors, which gives them the tendency to remain rotating. This stored energy can be particularly valuable when a large power plant fails, as it can temporarily make up for the power lost from the failed generator. This temporary response—which is typically available for a few seconds—allows the mechanical systems that control most power plants time to detect and respond to the failure.

Why Does It Matter?

Historically, in the U.S. power grid, inertia from conventional fossil, nuclear, and hydropower generators was abundant—and thus taken for granted in the planning and operations of the system. But as the grid evolves with increasing penetrations of inverter-based resources—e.g., wind, solar photovoltaics, and battery storage—that do not inherently provide inertia, questions have emerged about the need for inertia and its role in the future grid.

To educate policymakers and other interested stakeholders, NREL analysts have released a guide that provides an overview of inertia's role in maintaining a reliable power system, why inertia may decrease with increasing deployment of wind and solar generation, and how system reliability can be maintained in the evolving grid.

An accompanying video further illustrates several key concepts and is available at: https://youtu.be/b9JN7kj1tso

Key Takeaways (or Why We Shouldn't Panic)

1. **Grid frequency, which is a measure of the balance of supply of electricity and demand, can drop if a large power plant or transmission fails.** Inertia resists this drop in frequency, giving the grid time to rebalance supply and demand.
2. **Inertia is only one of several grid services that help maintain power system reliability.** Understanding the role of inertia requires understanding the interplay of inertia and these other services, particularly primary frequency response, which is largely derived from relatively slow-responding mechanical systems.
3. **The importance of inertia to a power system depends on many factors, including the size of the grid and how quickly generators in the grid can detect and respond to imbalances.** A grid with slower generators needs more inertia to maintain reliability than a grid that can respond quickly.
4. **Using power electronics, inverter-based resources including wind, solar, and storage can quickly detect frequency deviations and respond to system imbalances.** Tapping into electronic-based resources for this "fast frequency response" can enable response rates many times faster than traditional mechanical response from conventional generators, thereby reducing the need for inertia.
5. **Replacing conventional generators with inverter-based resources, including wind, solar, and certain types of energy storage, has two counterbalancing effects.** First, these resources decrease the amount of inertia available. But second, these resources can reduce the amount of inertia actually needed—and thus address the first effect. In combination, this represents a paradigm shift in how we think about providing frequency response.
6. In the United States, the Texas grid (the Electric Reliability Council of Texas, or ERCOT) is the smallest of three main grids. **ERCOT's relatively small size, combined with its large wind deployment, has required it to compensate for declining inertia by adopting several low-cost solutions, including allowing fast-responding noncritical loads to respond to changes in frequency.** This has enabled ERCOT to achieve increasingly high instantaneous wind penetrations—reaching a record of 58% in 2019—while maintaining reliability.
7. **In the Western and Eastern Interconnections, which are much larger than ERCOT, it is unlikely that any significant concerns related to maintaining frequency due to declining inertia will arise in the coming decade.** Moving forward, demonstrated solutions—including those used in ERCOT today—can allow these regions to add significant wind and solar while maintaining reliable operation.
8. **Ongoing research points to the possibility of maintaining grid frequency even in systems with very low or no inertia.** The development of new "grid-forming" inverters enable inverter-based resources to take a more active role in maintaining reliability and could be an integral technology for a purely inverter-based grid.

Although growth in inverter-based resources will reduce the amount of grid inertia, there are multiple solutions for maintaining or improving system reliability—so declines in inertia do not pose significant technical or economic barriers to significant growth in wind, solar, and storage to well beyond today's levels for most of the United States.

Get the Full Story

Watch the **video** at https://youtu.be/b9JN7kj1tso

Download the **report** at https://www.nrel.gov/docs/fy20osti/73856.pdf

Contact lead author **Paul Denholm** at Paul.Denholm@nrel.gov

Funding for this work was provided by

GridLAB