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Integration of Variable Generation and Cost-Causation

Integration Costs Are Generally Manageable, but Calculating Costs Is Challenging

Integration Costs Are Hard To Calculate Correctly

Variable renewable energy generation sources, such as wind and solar energy, provide benefits such as reduced environmental impact, zero fuel consumption, and low and stable costs. However, their variability and uncertainty—which change with weather conditions, time of day, and season—can mean increased power system operating costs.

The primary costs come from additional operating (flexibility) reserves needed to ensure system reliability and impacts on the operations of nonrenewable generation. Generally, integration costs have been found by various utilities to be manageable and modest compared with electricity prices, but there is little agreement on methodologies used to determine those costs or even whether they are measurable.

Although a number of studies have assessed integration costs, calculating them correctly is challenging because it is difficult to accurately develop a baseline scenario without variable generation (VG) that properly accounts for the energy value. It is also difficult to appropriately allocate costs given the complex, nonlinear interactions between resources and loads.

Analysis techniques are now very good at simulating power system operations with time-synchronized load, wind, and solar data. The best studies model security-constrained unit commitment and economic dispatch with hourly (or shorter) time steps covering one year or longer. They account for forecast errors of wind, solar, and load as well as actual output and consumption. Total system costs with and without renewables can be calculated accurately under a range of conditions. The cost differences are typically dominated by the fuel cost savings that renewables provide.

However, calculating an "integration cost" that includes only the added cost the power system incurs dealing with the variability and uncertainty of wind and solar is much more difficult. The many complex interactions among components of the power system and assumptions regarding the base case have important influences on integration cost estimates and raise questions about whether integration cost components can be correctly untangled. The complexity does not stem from an inability to model the power system or to calculate system costs with and without VG but rather from establishing what conditions to compare and the interactions among generation resources. Wind and solar integration costs cannot be measured directly.

Common Errors in Integration Analyses

Sometimes, mistakes are made in technical analyses of integration studies. The most common include:

- **Double counting**

  This usually results from failing to account for aggregation benefits or including the same variability or uncertainty in multiple services.

- **Fixing transaction schedules based on the without-wind case optimization and holding them for the with-wind case**

  This typically results in suboptimal resource scheduling and significantly higher balancing costs. A related error is the assumption that only a subset of generation is available for balancing response.

- **Calculating excessively high balancing costs assuming hourly scheduling, although sub-hourly scheduling is already operational in many regions**

  This restricts access to the response capability that physically exists in the generation mix.

- **Attempting to balance VG in isolation from load**
- **Scaling the output of existing VG to represent the expected output of a larger fleet**

  This greatly overstates the variability of wind and likely overstates the variability of solar.

Wind and solar forecast data sets must also be time-synchronized to historical weather patterns.

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Other Types of Generation Impose Integration Costs

Integration impacts and costs are not exclusive to wind and solar. Many types of generators impose costs when they are added to the electric power system. For example, large generators impose contingency reserve requirements, block schedules increase regulation requirements, gas scheduling restrictions impose system costs, nuclear plants increase cycling of other base-load generation, and hydro generators and others create minimum-load reliability problems. However, none of these costs is allocated to the generators that impose them on the power system.

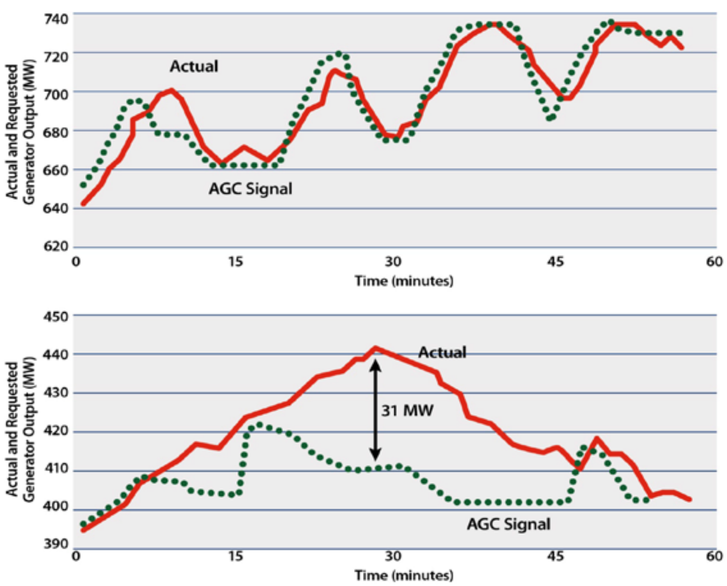

Figure 1. Two coal-fired generators in the Midwest illustrate a difference in ability to follow an automatic generation control (AGC) signal. The upper generator is providing regulation, while the lower generator is imposing a regulation burden of 31 MW on the power system.

The Future of Wind and Solar Integration Analysis

Progress in wind and solar integration analysis has been spurred on by the increasing amounts of wind and solar power being deployed in systems around the world. State-of-the-art wind and solar integration analysis now uses the same security-constrained unit commitment and economic dispatch software that is used to operate the electric power system. Numerical weather prediction mesoscale modeling, cloud-cover, and other weather models are used to generate wind and solar time-series data that are time-synchronized with actual load data. Modeling is done for multiple years with 10-minute or faster resolution. Wind and solar forecasts are included for unit commitment. A base case without VG is compared with one or more high-penetration VG cases to determine the impact of wind and solar on fuel and operating costs, reserve requirements, and the operation of conventional generators. Total system costs with and without VG can be calculated with reasonably high confidence.

Although there are technical difficulties calculating VG integration costs, there are also public policy and regulatory questions concerning what to do with the integration costs of renewables, if they can be accurately calculated. Other generation technologies impose integration costs that are not allocated to those technologies. Assigning integration costs should be thought through very carefully to ensure they are not discriminatory. Generation integration costs are typically broadly shared because the benefits are also broadly shared. Contingency reserves are shared within a large reserve sharing pool because aggregation reduces the physical reserve requirement and therefore reduces everyone's costs. Variable renewables bring fuel diversity, price stability, energy security, and environmental benefits that accrue widely to all users of the power system. With such broad and intertwined benefits, integration costs could either be broadly shared or be assessed based on performance, not generation type.

Associated Publications

Milligan, M.; Ela, E.; Hodge, B.-M.; Kirby, B.; Lew, D.; Clark, C.; DeCesaro, J.; Lynn, K. (2011). *Cost-Causation and Integration Cost Analysis for Variable Generation*. NREL/TP-5500-51860. Golden, Colorado: National Renewable Energy Laboratory. www.nrel.gov/docs/fy11osti/51860.pdf.

Milligan, M.; Ela, E.; Hodge, B.-M.; Kirby, B.; Lew, D.; Clark, C.; DeCesaro, J.; Lynn, K. (2011). "Integration of Variable Generation, Cost-Causation, and Integration Costs." *Electricity Journal* (24:9); pp. 51–63.

More Information

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