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MJB&A Discussion Paper ■ December 10, 2012

Managing Renewable Energy Integration

According to projections by the U.S. Energy Information Administration (EIA), from 2010 to 2040, U.S. electricity sales will grow by 23 percent. EIA projects that 35 percent of the new generation required to meet demand will come from non-hydropower renewable energy sources such as wind and solar, while 56 percent will come from natural gas.

As more renewable energy sources are brought onto the grid, grid operators will rely on an expanding mix of tools to integrate renewable energy sources while providing reliable power. This paper focuses on the use of flexible generation, such as that provided by natural gas turbines, in the transition to a cleaner, diverse generating fleet.

Projected Growth in Renewable Energy Generation

Since 2005, the share of the nation's electricity supplied by non-hydroelectric renewable resources has doubled from two percent to four percent. EIA predicts that by 2025 renewable generation will double again to more than eight percent of the nation's electricity supply. Much of the expected future growth will come from the need to meet state renewable portfolio standard (RPS) requirements.

Thirty states and the District of Columbia currently have established RPS programs, which typically require electricity suppliers to meet a portion of their load with qualified renewable resources. These jurisdictions represent about 64 percent of the nation's electricity consumption.

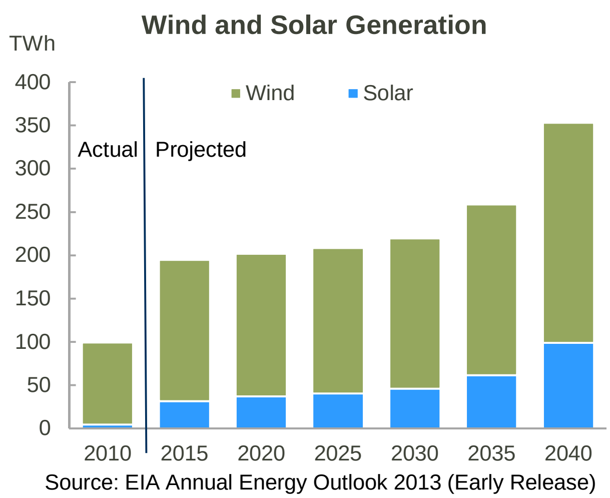


Figure 1. Projected Annual Wind and Solar Generation

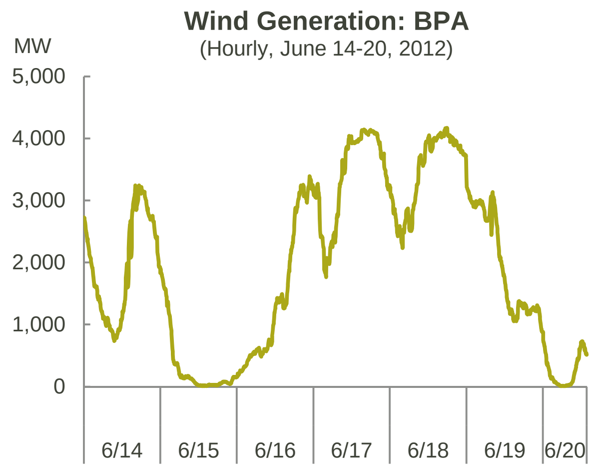
Electric System Overview

Electric generating facilities, ranging from large coal-fired power plants to small solar installations, have a wide range of operating characteristics and each type of facility brings different attributes to the electric system. One technology cannot always directly substitute for another. There is a certain base demand for power that remains constant throughout any given day. Power plants that can be dispatched by power grid operators, and are least expensive to run, operate almost continuously to satisfy this minimum level of demand, or "baseload." Resources with these characteristics include baseload coal-fired, natural gas-fired, biomass, hydroelectric and nuclear power plants which often run close to their full capacity, as long as fuel is available, and are not regularly cycled on and off. When demand for electricity fluctuates seasonally or over the course of a day, system operators may call on additional power plants (these are sometimes called "intermediate" units) to provide power. Depending on the region of the country and the mix of electric power resources, this increased demand may be met by additional coal- or natural gas-fired power plants.

During periods of peak power demand, system operators may rely on natural gas turbines that are able to ramp up quickly and provide electricity. These "peaking" units might only operate 10 percent of the time in any given year.

Integration of Renewable Energy Sources

As renewable energy sources are added to the electric grid, sytem operators have to manage the bulk electric system to accommodate the electricity from renewable sources when it becomes available. Whereas conventional thermal resources such as coal-fired power plants and natural gas turbines turn output up and down by increasing or decreasing fuel consumption in response to electricity demands, variable renewable energy sources such as wind and solar increase and decrease output based on wind and daylight conditions. These factors may or may not be correlated with demand and are outside the control of system operators. In order to keep supply and demand of electricity evenly balanced, grid operators must address the variability of output from these energy sources, and the uncertainty associated with the timing and magnitude of that variability.



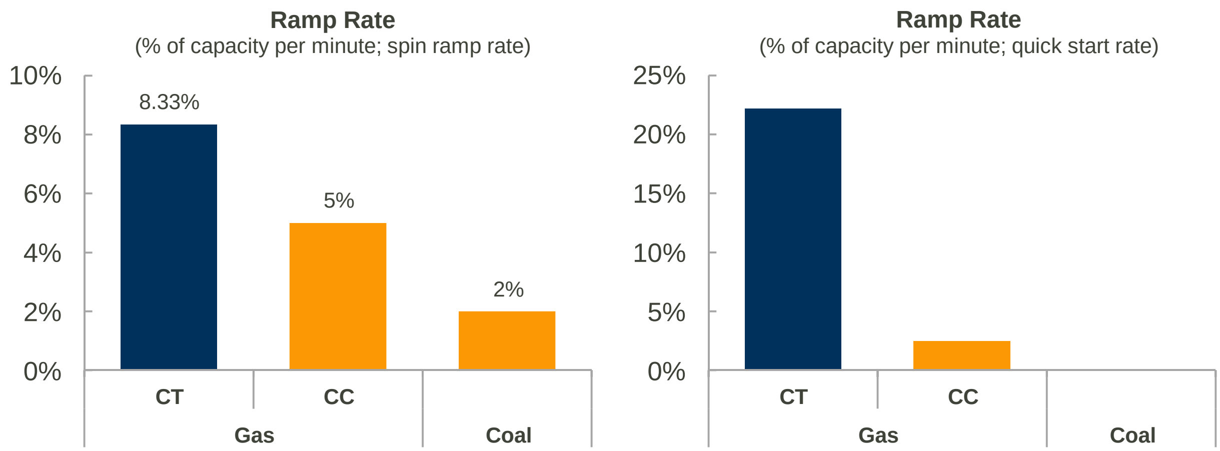
Source: MJB&A Analysis (based on data from Bonneville Power Administration)

Figure 2. Hourly Wind Generation Reported by BPA from June 14 to 20, 2012

Figure 2 shows wind generation on an hourly basis as reported by the Bonneville Power Administration (BPA) in the Northwest U.S. While this graphic shows only one week of data, it illustrates the type of variability expected from wind energy sources. The output from wind varies from day to day and even hour to hour. One tool available to system operators to address this variability is wind resource forecasting. While forecasting has become increasingly sophisticated in recent years and is continually improving, it remains an inexact science.

Variability and forecast errors are expected and accounted for when wind and solar generators bid into electricity markets. When system operators expect significant contributions from wind or solar generation, they ensure that adequate "dispatchable" resources—those able to produce electricity on demand—are available to pick up any drop in output from variable resources. A drop may be part of the expected forecast or occur unexpectedly.

Addressing small fluctuations is relatively straightforward, as the system operator can adjust energy output from units that are already running. Addressing larger swings requires dynamic management of the electric system and poses a greater challenge to system operators. There are a number of technologies that can be used to begin to address the challenges of integrating renewable energy sources at a larger scale, such as frequency regulation, energy storage, and integration with conventional plants. However, the most basic form of support is flexible generation that plant operators can quickly turn on at the request of grid operators. Whereas large steam-based fossil fuel-fired generating units can take hours to reach full capacity, natural gas combustion turbines have the ability to ramp up and provide power very quickly. Figure 3 compares the spinning and quick start ramp rates of combustion turbines (CT), natural gas combined cycle units (CC), and coal units. Spinning ramp rates reflect the rate at which a unit can ramp up capacity when its turbine is already spinning and synchronized with the grid; quick start ramp rates reflect the rate at which a unit can ramp up when its turbine is not synchronize with the grid. Using technology similar to that of a jet engine, natural gas CTs can ramp up much faster than other thermal resources under either condition and have a particular advantage under quick start conditions. Several major manufacturers advertise newer gas-fired turbines with 10-minute startup times. These natural gas turbines can be called into service in response to short-term drop-offs in wind or solar capacity. The presence of CTs in the system provides grid operators the freedom to accept capacity from renewable energy sources without putting electric system reliability at risk. Recognizing the natural opportunity to pair natural gas and renewable capacity, gas turbine manufacturers have developed advanced CC technologies that ramp at rates approaching 10 percent while maintaining the higher combustion efficiencies associated with combined cycle operation.



Source: Black & Veatch

Figure 3. Spin Ramp Rates and Quick Start Rates of Thermal Electricity Resources

Action Underway to Integrate Renewable Energy Resources

Without adequate resource planning, increased reliance on intermittent renewable resources can stress grid reliability especially in areas such as Texas and the Pacific Northwest that have the greatest amounts of installed wind capacity. Grid operators in these areas already use many of the available tools to manage fluctuations in output from these resources. ERCOT, which manages the grid in Texas and has the highest installed wind capacity of any U.S. state, has done extensive work to improve wind forecasting, incorporate forecast uncertainty into its reserve requirements (for quick-response resources like natural gas turbines), and improve system modeling to account for wind resource variability.

In the Pacific Northwest, BPA has a Wind Integration Team to help BPA and other regional utilities operate reliably and cost-effectively with large amounts of wind power. One of the unique characteristics of the Pacific Northwest is the large hydropower resource. In addition to balancing wind variability, BPA has to maintain safe water levels in its hydropower reservoirs. To address the challenges of managing wind and hydro resources simultaneously, the BPA Wind Integration Team has undertaken a number of initiatives including implementing operating protocols and communication tools to limit wind generation in response to other deployed generation (such as hydropower or thermal resources), piloting a program to enable wind generators to supply their own contracted dispatchable resources (such as natural gas turbines) in response to generation imbalances, and improving wind forecasting.

Long-term Management of the Integration of Renewable Energy Resources

As more renewable energy is added to the electric system in response to the policy drivers like state RPS requirements and federal tax credits, the tools currently under development at the regional level will undergo continued refinement and expansion. A 2011 report by the Massachusetts Institute of Technology (MIT) entitled *The Future of the Electric Grid* found that "one of the most important emerging challenges facing the grid is the need to incorporate more renewable generation in response to policy initatives at both the state and federal levels." The National Renewable Energy Laboratory (NREL) has identified the major technologies and practices that can be used to manage this challenge:

- *Flexible conventional generation:* Thermal generation that can be quickly ramped up or down such as natural gas combustion turbines. EIA projects the addition of 290 gigawatts (GW) of total generating capacity by 2040. Of that capacity, over 190 GW are expected to be natural gas-fired generation, with over 80 GW in the form of combustion turbines. Natural gas turbines have a number of attributes that make them uniquely appropriate for supporting (or firming) the grid as renewable assets are added to the system.

- *Flexible renewable generation:* Through the use of advanced technology, renewable resources can be made more flexible. System operators can require that variable capacity like wind or solar generation be built with technology that allows it to be curtailed when demand drops. In addition, hydropower and geothermal energy can be dispatched in response to demand.

- *Flexible load:* Demand-side programs that shift load away from peak periods through incentives or dynamic pricing can help to improve the match between demand and supply.

- *Energy storage:* Storage technologies allow system operators to store electricity when it is generated and access it on demand.

- *Resource sharing and spatial diversity:* Expanding transmission and interconnections to increase the size of balancing areas can help improve the match between supply and demand.

NREL also emphasized the need for continued innovation in the flexibility of conventional generating technologies, as well as in forecasting for variable energy resources.

Additional Examples and Observations

- Independent System Operators (ISOs) in the U.S. have been studying the impact of renewable standards on regional electric grids. A 2010 report by the California ISO found that "Gas plants are particularly important because they currently provide most of the ramping and ancillary service capability for the ISO."
- As variable energy resources are added to the electric system, there are a number of innovative approaches to match variable renewable resources with conventional forms of generation. In 2010, the Bonneville Power Administration (BPA) launched a pilot project to support additional wind power on the transmission grid. BPA purchased 75 megawatts of generation reserves from a Calpine Corporation natural gas fired plant in Hermiston, Oregon. When wind generators over produce, BPA can ask Calpine to reduce its natural gas-fired generation. Calpine will then buy the excess power on BPA's system to fulfill its existing obligations to customers. The arrangement optimizes use of renewable resources while maintaining power system reliability.

- *The Future of Natural Gas*, a 2011 report by MIT, found that "Natural gas-fired power generation provides the major source of backup to intermittent renewable supplies in most U.S. markets" and that such capacity will be needed to provide system reliability in the future.
- Gas turbine manufacturers have responded to the demand for turbines that can complement variable electricity sources by designing combined cycle units that have fast ramp rates. Siemens has a 570 megawatt (MW) combined cycle unit (SCC5-8000H) that has an advertised efficiency of 60.75 percent and can ramp up at 35 MW per minute. GE recently introduced a combined cycle plant (FlexEfficiency 60) that has a reported efficiency greater than 61 percent and can ramp at a rate of 100 MW per minute. Alstom has a 500 MW combined cycle plant (KA26) with advertised efficiencies of 59 percent and a ramp rate of over 20 MW per minute.
- Changes to electric system operation to accommodate larger contributions from variable renewable energy sources are already underway at the federal level, through decisions made by the Federal Energy Regulatory Commission, and at the regional level through the deployment of management strategies by regional grid operators.
- Strategies to integrate variable renewable resources like wind and solar will vary by region of the country, depending on the existing infrastructure and the types of renewable resources that need to be integrated.

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