Featured Articles

Filling the Wires: Operational Strategies to More Efficiently Deliver Wind Energy

Contributed by:
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In recent editorials, T. Boone Pickens has urged the United States to aggressively develop what he calls the "Saudi Arabia of the Wind"—the portion of the western United States from west Texas to Canada, stretching over a vast expanse of the West and the Great Plains.[1] As we all know, this area is where the great wind is, but it is not where most of the country's population is located.

The United States has a great demand for wind generation in areas surrounding this wind heartland, particularly up and down the West Coast and in the Midwest. As Mr. Pickens points out, exploitation of this vast wind-generation resource, available where the wind blows hardest and most steadily, is greatly hampered by a lack of economical long-distance transmission facilities.

The challenge is to bring wind to the load centers inexpensively. A utility must build or purchase use of high-voltage transmission facilities 1,000 to 1,500 or more miles in length to reach superior wind resources. At the capacity factor[2] of even the best wind resources, utilities have evaluated a wind resource-driven transmission line used only at the 40 to 45 percent capacity factors of the best wind resources, and often have paled on considering the cost per megawatt-hour. Although the escalating cost, both economic and environmental, of fossil fuels may make the long-distance wind-generation line look more attractive, proper integration of technology and utility operations can make the clean choice also a much more economical choice. A fully integrated wind delivery system can make much higher use of new transmission lines, with large cost savings. Accordingly, any transmission plan that looks only to the instantaneous capacity of a new transmission path will significantly overprice the cost of tapping our wind "Saudi Arabia."

Why Economical Interregional Transmission of Wind Generation Is Especially Difficult

Integration of wind energy is not easy. Any long-distance transmission of large amounts of electric generation presents electrical engineering challenges. Utility engineers routinely surmount such challenges in the construction of long-distance transmission systems for conventional electric generation systems. However, transportation of wind by wire must also accommodate special characteristics of wind generation. Briefly, these key special characteristics are:

1. Low Capacity Factor. Even in the most energetic wind areas, sites with generation capacity factors of 40 to 45 percent are considered premium sites. By comparison, large thermal generation units can achieve capacity factors in the 85 to 95 percent range. Long high-voltage transmission lines are very expensive, and the reduced capacity factors for wind generation translate to a roughly 2-to-1 cost transmission disadvantage for long hauls of wind-generation megawatt-hours.[3]
2. Hourly Forecasting Difficulty. Despite continuing improvements in wind forecasting techniques, actual wind generation in each hour can vary substantially from forecast levels.[4] Generally, the geographic areas with the best wind potential are not part of any organized regional transmission organization with centralized dispatch. Instead, each transmitting utility schedules out-of-region deliveries of wind generation based on forecasts and may impose substantial charges for deviations between forecast and actual generation.
3. Intrahour Swings in Generation. Wind generation, even if produced over an hour *on average* in the amount forecast, may vary greatly within the hour. The within-hour output swings can be particularly noticeable as weather fronts pass through.[5] Although the Federal Energy Regulatory Commission's (FERC) Open Access Transmission Tariff does not address the cost of such intrahour variations, transmission providers are beginning to assess sometimes substantial new transmission ancillary service charges to cover the supposed cost of such generation swings.[6]

As a result of these aspects of wind-generation intermittency, the cost per megawatt-hour of relocating wind generation to other regions can be much higher than the cost of similarly relocating thermal generation. An even greater problem arises when control area operators in the regions where the wind generation facilities are located maintain that they lack the generation flexibility required to provide the necessary hour-to-hour and within-hour shaping of the wind generation required for interregional deliveries.

Wind Storage Is an Important Tool

Currently, energy storage capital products are being touted to deal with the wind delivery problems. Such projects certainly are an important part of the solution. They often, however, require expensive new capital investment. Moreover, in all cases, storage through mechanical devices results in loss of a portion of the energy initially generated, as no storage device can be perfectly efficient. The losses vary by technology but impose significant costs.

Mechanical storage devices are part of the total package, but should be used only to supplement and after exhaustion of the types of low-cost operational measures described below.

Operational Measures Now in Use to Support Economical Interregional Transmission of Electric Generation

Some of the tools needed to overcome the economic barriers to long-distance transmission of wind generation are already in limited use. More creative new approaches are also available. Current tools include:

1. Dynamic Scheduling. Wind generation could be telemetered directly into the control area of the distant utility purchaser. With such telemetering, for example, the generation from a Wyoming generation facility sold to Southern California Edison Company could be followed by the centralized dispatch of the California Independent System Operator, rather than by a control area operator in Wyoming. Although dynamic scheduling requires an uncongested transmission path and can present engineering challenges, it has been used frequently in the United States, including for large deliveries of generation capacity over long distances.

   Dynamic scheduling is particularly important for projects located in the wind heartland. The high-wind areas are the very areas lacking regional transmission organizations and centralized energy markets. Dynamic scheduling allows the wind to be taken directly into such markets as the California Independent System Operator area, the Midwest Independent Transmission System Operator area or the PJM Interconnection Association area for shaping near the load centers.

2. Storage and Exchange Arrangements. Utilities have contracted to take the output of localized wind generation to serve local loads in real time each hour, and then deliver an equivalent amount of electricity at a new location convenient to the ultimate output purchaser.[7] Under such "storage and exchange arrangements," a purchaser can receive wind-generation output from an exchanging utility at a prescheduled rate of delivery. The wind generators under the currently effective agreements have not needed to purchase generation-following or intrahour-variation services. Moreover, the deliveries can be arranged so as to bypass transmission constraints, allowing more generation to be constructed without transmission additions. Finally, because of the delivery provided by the storage and exchange arrangements, the wind-generation owners under the current agreements have avoided the cost of purchasing firm transmission rights equal to the installed capacity of the generation facilities.

Expansion of These Tools to Reduce the Cost of Interregional Transmission of Wind Generation

The existing tools used to supplement transmission of electricity suggest new or modified contractual arrangements that could reduce the cost of interregional delivery of wind generation. Below are some examples.

1. Expansion of the Use of Dynamic Scheduling.

FERC should require that a transmitting utility either grant dynamic scheduling requests or demonstrate that the requested service is not feasible. If the transmitting utility maintains that its current system would not support such service, it should be required to perform a study and determine the incremental cost of satisfying the request for dynamic service, and then it should be required to offer such service at cost.

2. Adaptation of Storage and Exchange Arrangements as Flexible Transmission Service.

Current wind storage arrangements are inexpensive, but not very efficient for shaping large quantities of wind electric generation. Current arrangements normally provide for 168-hour-delayed delivery. That is, the amount of wind generation received by the storing utility is delivered in the same hour of the following week. This protocol is equitable, in that the average value of energy received and delivered should be comparable. The protocol, however, is inflexible and will cause the storage capacity of utilities to be exhausted far too quickly.

Take the following example: In hour 1, wind generation was 200 average megawatts, but the deliveries by the storing utility were 0 average megawatts, based on the actual wind-electric generation the prior week. The utility is required to back down 200 average megawatts of its other generation. Then, if the wind is not blowing a week later, the 200 average megawatts must be delivered by the storing utility, and the utility must use 200 megawatts of what might otherwise be its capacity reserves to make the deliveries.

If FERC so required, the transmitting utility could provide the wind developer and the wind-generation output offtaker with far more efficient adaptations of current storage and exchange arrangements designed to reduce or eliminate the burden on the applicable control area operator of inter- and intrahour generation variations. Such reduction in burden is possible because the control area operator under storage and exchange arrangements both accepts wind-generation output and delivers equivalent output to a new wholesale load. The combination of power deliveries and sales offers opportunities for creative and flexible arrangements beneficial to both the wind generator and the control area operator.

Note that not all changes in wind-generation output burden the control area operator. A ramp-up in generation is helpful if load also is ramping up. Likewise, a ramp-down in generation is helpful if load is ramping down. In hours when the control area operator faces the greatest stress from high-load requirements, it would benefit if it could receive wind-generation output in excess of the wholesale wind-offtaker load it concurrently has to meet. In hours when the control area operator faces minimum generation constraints, it would benefit if it could serve wholesale wind-offtaker load in excess of concurrent wind-generation output.

A classic system that could benefit from such flexibility is the Bonneville Power Administration (Bonneville), located in the Pacific Northwest. Bonneville has in place the type of 168-hour delayed storage service noted above. Bonneville also experiences situations in which it is required to take excess wind energy into its system at night, when it is operationally constrained by having loads less than the generation required for it to meet its minimum streamflow requirements. A requirement to take excess wind generation at such times could force Bonneville to spill water past its dams, for a net loss of energy. Likewise, during high load periods, Bonneville can face constraints in its sustained peak delivery capacity. If Bonneville's obligation to deliver stored wind energy in such periods exceeds actual wind electric generation in the applicable hours, Bonneville may need to maintain additional capacity reserves, to the detriment of other load service.

Creative storage arrangements, however, could turn wind into an operational benefit for Bonneville. It should be able to deliver a great deal more storage service, at low rates, if (a) it has the right to advance wind deliveries during minimum flow periods, and (b) it has the right to reshape wind deliveries out of its capacity-strained periods. One of Bonneville's biggest operational problems is its inability to shape its loads to address generation challenges arising from its increasingly difficult streamflow restrictions. Creative interregional wind energy receipt and delivery arrangements can ease, rather than exacerbate, this operational challenge.

With FERC's encouragement, transmitting utilities, wind-generation developers and wind output offtakers could devise storage and exchange arrangements that better match the needs of wind-generation and control area operators, and that therefore allow much more wind generation to be economically shaped and delivered from region to region.

3. <u>Use of Storage and Exchange Arrangements to Increase the Use of New Long-Haul Transmission Facilities.</u>

Generation planners have struggled with approaches to overcome the relatively low capacity factors anticipated for new long-haul transmission facilities to wind-rich areas. One proposed approach is to interconnect megawatts of wind generation in excess of the firm carrying capacity of such transmission facilities. This approach would at times require partial curtailment of the wind generation; however, such curtailments have been shown to be relatively small as a percentage of total wind generation.[8]

This "excess capacity" approach to increasing transmission facility use could be substantially enhanced through properly designed transmission, wind storage and exchange arrangements. The cost of curtailing wind generation is high, generally approximating the sum of lost energy sales revenues, related lost sales of environmental attributes and the grossed-up value of related lost production tax credits. Even limited storage and exchange arrangements, with the control area operator taking excess wind generation on the relatively rare occasions when the generation exceeds transmission capacity for delivery during future periods of low wind generation, would greatly reduce the cost of an excess capacity strategy. Moreover, if the control area operator were given qualified rights to select when during low-wind periods it would redeliver the excess wind generation it had stored, as described above, the benefits to the control area operator of such flexibility could offset the cost to the control area operator of the storage and exchange arrangements. If FERC required cost-based services of this sort, the net cost of such products to the transmission provider, after credit for flexibility benefits concurrently provided to the control area operator, could prove small or nonexistent.

For example, through arrangements with local utilities, a transmission line owner might sign up 1,500 megawatts of wind generation for a transmission facility with only 1,000 megawatts of firm capacity. In periods in which total generation exceeded 1,000 megawatts, the first obligation of the transmission owner might be to acquire short-term transmission. Note that the absence of firm transmission does not mean that there is no additional transmission in all hours; often the shortage is only seasonal, or indeed may appear only for a relatively few hours each year. At this step, the actions of the transmission owner closely resemble what a provider of conditional firm service might do. Then, however, for those hours in which an absolute shortage of firm transmission exists, the local utility or utilities, by contract, could agree to a schedule for taking the excess generation into their systems to meet local loads. In return for the burden of forced taking of generation of limited amounts during relatively limited periods, the storing utility might be given substantial discretion as to when to make the redelivery, with the only constraint being that unused capacity exists on the transmission line in the delivery hour. The storing utility then could make the delivery at a relatively beneficial time to it.

The advantage to the wind generators and their customers in this example is that if the wind generation has a 40 percent capacity factor, by fully integrating 1,500 megawatts onto a 1,000 megawatt capacity addition, the parties could raise the effective use of the incremental transmission to a 60 percent capacity factor. With mechanical storage added as part of the tool package, the usage could even be substantially higher. When considering the cost of a high-voltage line of 1,000 miles or longer, the cost savings per megawatt-hour would be large indeed.

FERC, Regional Transmission Organizations, and State Regulators Could Strongly Promote Wind-Generation Expansion by Promoting and Supporting the Types of Transmission Arrangements Described in This Article

Transmitting utilities are not now required to provide dynamic scheduling or the storage and exchange arrangements described above. Without such enhancements to transmission service flexibility, interregional transmission of wind generation will remain unnecessarily constrained and costly. FERC could perform a valuable service by holding technical conferences to explore how cost-based transmission ancillary service could be better adapted to facilitate the long-distance transmission of wind generation from wind-rich areas to wind-generation-deficient regions.

In addition, regional transmission organization-like entities in the affected region, such as Columbia Grid or Northern Tier Transmission Association, could work with wind generators and their customers to create the necessary storage arrangements. Such cooperative arrangements could be beneficial to wind generators, their customers, and the storing utilities alike.

Finally, state regulators implementing greenhouse gas reduction statutes will need to recognize the carbon-reduction impacts of wind-generation storage arrangements. To the extent that a storage arrangement permits wind generation to meet any utility's load requirements in real time, carbon-free generation will result. The utility to which the stored wind generation is delivered usually is accorded green tags for the generation, in recognition of the fact that it has paid for and thus is responsible for the green generation. However, state greenhouse gas rules must also properly allocate the greenhouse gas benefit to the utility that has paid for the output of the wind generation facility to be produced, stored and redelivered. State regulators need to be educated as to the benefits of shaping arrangements, so that they properly allocate greenhouse gas reductions to the ultimate purchaser of stored wind generation from thermal systems.

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[1] This article primarily addresses wind generation that would be located in that wind-rich area extending from eastern Washington and Oregon, east across Idaho, Montana and the Dakotas, and south through Wyoming. This region spans multiple electric reliability areas, one of which (the Western Electricity Coordinating Area) is not synchronously connected with the others.

[2] "Capacity factor" refers to the ratio between the average generation and the capacity of a generation resource. A 1 megawatt resource, operating at full capacity for a year, can produce 8,760 megawatt-hours of electricity. If that resource were an intermittent wind resource that produced, for example, 3,504 megawatt-hours in a year, its annual capacity factor would be 3,504 MWh/8670 MWh, or 40 percent.

[3] Some have suggested that wind-generation owners might resell unused firm transmission capacity during light wind periods. However, we have not seen cases in which such short-term sales of transmission are expected to bring in substantial revenues.

[4] For an excellent analysis of the impacts of forecasting errors, see the discussion in the California Independent System Operator Corporation's report, *Integration of Renewable Resources* (Nov. 2007), *at* http://www.caiso.com/1ca5/1ca5a7a026270.pdf.

[5] See the analysis of intrahour wind-generation ramping in "Integration of Renewable Resources," *supra* note 4.

[6] For example, the Bonneville Power Administration has established a wind integration charge to ensure that the costs of wind-generation integration can be borne by the parties causing the costs—mostly purchasing utilities outside of its control area.

[7] Typically, the utility purchasing the wind generation, rather than the utility providing the storage service, controls the renewable energy credits associated with the purchase and thereby takes credit for delivery of clean energy to its customers.

[8] See, for example, Debbie Lew & Michael Milligan, National Renewable Energy Laboratory, *New Approaches to Deliver Wind Energy* (May 21, 2007), *at* http://www.nrel.gov/wind/systemsintegration/pdfs/2007/lew_delivering_wind.pdf.

Climate Change Suits Against Fossil Fuel Power: Will They Get Hotter Or Colder?

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The village of Kivalina, Alaska, located eighty miles north of the Arctic Circle on a barrier island, is falling into the sea. Since the early 1980s, sea ice—which protects the island from storm surges—has been forming later and melting earlier. As a result, Kivalina is exposed to more winter storms of increasing severity. In 2006, the U.S. Army Corps of Engineers (CoE) concluded that the situation in Kivalina had become "dire" and that the entire town would have to be relocated within six years. A group of four hundred Kivalina residents have filed suit against twenty petroleum producers, coal-burning utilities, and other energy companies, asserting that their carbon dioxide (CO_2) emissions create a public nuisance