



GUEST EDITORIAL

It's in the Air

Increased wind integration around the globe

Charles J. Smith and Brian Parsons

It is a great pleasure for Brian Parsons of the National Renewable Energy Laboratory (NREL) and myself to once again serve as guest editors of *IEEE Power & Energy Magazine*. This special issue is dedicated to the integration of wind power plants into power system planning and operations. It has been truly phenomenal to watch the explosion of interest and information about this topic in the past five years. We have gone from a situation in which wind energy was a boutique business that was not taken very seriously to one in which wind now accounts for the second-largest share of new generating capacity installed in the past year (just behind natural gas).

Wind has progressed from a small activity in the IEEE Power & Energy Society (PES) to a major focus of the annual PES meetings and the subject of a coordinating committee because of its pervasive influence on PES. The Utility Wind Integration Group (UWIG), a technical organization that deals with identifying and addressing issues associated with the integration of increasing amounts of wind power into power systems, has grown from six members in 1989 to more than 150 members 20 years later. We have all come quite a long way, but we still have a long way to go.

In this editorial, we would like to review some of the major activities in the technical and policy world that are helping to shape the landscape around wind developments. When was the last time you heard renewable energy and national transmission policy discussed in a U.S. presidential debate or inaugural address? There have been numerous events that have had major impacts on the course of wind energy development in the past year; we will pick out a few of the biggest ones to help provide some context for the changing environment in general and for this issue in particular.

The major activities on which we will focus are the U.S. Department of Energy (DOE) report "20% Wind Energy by 2030," which we previewed in the November/December 2007 issue, and the North American Electric Reliability Corporation (NERC) Integrating Variable Generation Task Force (IVGTF) report, released in April of this year. On the policy front, we will review the production tax credit (PTC), the renewable electricity standard (RES), and carbon policy, and we will make reference to the ongoing transmission policy discussion, which will be covered in more detail by Rob Gramlich, the senior vice president for policy at the American Wind Energy Association (AWEA), in the "In My View" column.

The DOE 20% Report

In 2006, President Bush articulated a national imperative for greater energy efficiency and a more diversified energy portfolio. Citing wind energy as part of the solution, he noted that areas of the nation with good wind resources could satisfy up to 20% of America's total electricity needs. Subsequently, government and industry came together to thoroughly explore the issues associated with a large expansion of wind generation. On 12 May 2008, the DOE released a groundbreaking report, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electric Supply*. According to Andy Karsner, then the DOE's assistant secretary of energy efficiency and renewable energy, "DOE's wind report is a thorough look at America's wind resource, its industrial capabilities, and future energy prices,

and confirms the viability and commercial maturity of wind as a major contributor to America's energy needs, now and in the future. To dramatically reduce greenhouse gas emissions and enhance our energy security, clean power generation at the gigawatt scale will be necessary and will require us to take a comprehensive approach to scaling renewable wind power, streamlining siting and permitting processes, and expanding the domestic wind-manufacturing base.”

The report found that a 20% wind contribution to U.S. electricity supply in 2030 would:

- reduce carbon dioxide emissions from electricity generation by 25% from current levels
- reduce natural gas use by 11%
- reduce water consumption associated with electricity generation by four trillion gallons
- increase annual revenues to local communities by more than US\$1.5 billion
- support roughly 500,000 jobs in the United States, with an average of more than 150,000 workers directly employed by the wind industry.

According to the DOE report, total electric costs would only increase 2% over a baseline scenario without wind, resulting in an average residential rate impact of US\$0.50 per month. However, downward pressure on natural gas prices would result in an overall consumer benefit when nonelectric gas cost savings are considered.

These benefits will not be realized under business-as-usual practices. Ramping up manufacturing, supplying technical personnel, realizing turbine performance improvements and capital cost reductions relative to other technologies, and managing the grid challenges discussed below will all require significant attention. The report postulates installation of a total of more than 300,000 MW of nameplate wind capacity by 2030. AWEA estimates current installed capacity to be in excess of 25,000 MW at the beginning of 2009, with a total of perhaps 30,000 MW by the end of 2009.

PES members should note there are significant grid-related challenges as well. The 20% wind scenario discussed in the DOE report would require the continuing evolution of transmission planning and system operations, in addition to expanded electricity markets. American Electric Power, which owns the nation's largest electricity transmission network in the United States, conceptualized a national high-voltage transmission upgrade that accommodated the wind scenario. A need for 19,000 miles of new corridor costing approximately US\$60 billion over 20 years was estimated. Achieving this necessary expansion will require extensive efforts to streamline and reform siting and permitting procedures, with federal leadership and jurisdictional cooperation on cost allocation and cost recovery likely.

Grid policy, market, and operational challenges were found to be manageable, but the report identified the need to:

- deploy more-flexible generation and load technologies
- improve the use of wind plant output forecasting tools
- improve grid codes and wind plant models
- aggregate wind plant output over large regions
- improve balancing area cooperation, including reserve sharing
- develop well-functioning day-ahead, hour-ahead, and real-time energy and price responsive load markets and expand access to those markets
- adopt market rules and tariff provisions that are more appropriate to weather-driven resources
- make better use of physically (as opposed to contractually) available transmission capacity
- eliminate pancaked transmission rates.

Since the DOE report was issued, these grid issues have formed the basis for the DOE wind program's research and outreach efforts and for much of the industry's research agenda. IEEE committees and PES members are already playing a vital role in addressing these challenges, and we believe the future holds exciting opportunities to continue these efforts.

Policy Environment

Historically, annual U.S. capacity additions of wind generation have been strongly driven by the on-again, off-again federal renewable energy production tax credit (PTC). The provisions, adjusted for inflation, currently give a 2.1 cent/kWh tax credit to the owners of qualified generation plants. Short-term PTC extensions and lapses in 1999, 2001, and 2003 have been disruptive and have caused boom-and-bust cycles of employment for developers and manufacturers. In February 2009, as part of the American Recovery and Reinvestment Act, the credit was extended for a three-year period through 31 December 2012. In recognition of the challenging economic times, plants completed or under construction by the close of 2010 can convert the PTC to an up-front 30% capital cost buy-down investment tax credit, convertible to a U.S. Treasury Department grant. The multiyear extension and grant provisions are expected to be beneficial, but this year's installation rate is expected to be well below 2008's record pace of 8.5 GW.

Wind-capacity additions are also strongly driven by state policies. As of July 2009, 30 states and the District of Columbia have established renewable portfolio standards that require increasing electric generation from wind and other specified sources. Of these 30 states, 18 have increased their goals from earlier levels. Six other states have put goals in place, without penalty provisions. Details of the various standards are summarized at <http://www.ferc.gov/market-oversight/mkt-electric/overview/elec-ovr-rps.pdf>, but most states specify that 15% to 25% of annual electric sales should be from renewable sources by 2020 or 2025. These provisions add up to more than 75 GW of new renewable capacity; much of that is expected to be wind capacity.

State provisions are far from uniform. At press time, a national renewable energy standard (RES) of 15–25% was being debated in the U.S. Congress. It has been estimated by the Union of Concerned Scientists that a 20% national standard by 2025 would result in around 117 GW of new renewable capacity by 2025. The effect on electricity prices, as estimated by EIA and others, is projected to be moderate: less than a 1% average increase with a 15% national RES.

Ten states in the Northeast and Mid-Atlantic have initiated a mandatory, market-based cap-and-trade program that took effect at the start of 2009. The Regional Greenhouse Gas Initiative (RGGI) aims to reduce CO₂ emissions from the power sector by 10% by 2018. Utilities in ten states, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont, are now required to purchase carbon emission rights. Credit prices and concerns about comparative economic competitiveness among participating and nonparticipating states have made the start-up rocky. Legislative carbon provisions have also been under national debate this year. The U.S. Energy Information Administration (EIA) has estimated that a 25% RES would only reduce carbon emissions by 7–12%, so any cap-and-trade goals beyond such an RES are expected to further increase wind-capacity deployment. At the time of this writing, a carbon cap-and-trade bill had been passed by the U.S. House of Representatives and was being debated in the Senate.

NERC's IVGTF Report

The press release from NERC that accompanied the release of its IVGTF report, “Accommodating High Levels of Variable Generation,” on 16 April of this year led off by saying, “Reliably integrating larger amounts of wind, solar, and other variable generation into the bulk power system will require changes to the way the system is planned and operated.” This statement was a remarkable summary of a remarkable report, which was the outcome of two years of work by a group of 50 individuals from across the spectrum of the electric power industry and the research and academic communities. The group was chaired by Warren Frost, vice president for operations and reliability for the Alberta (Canada) Electric System Operator, and staffed from the NERC side by Mark Lauby, its manager of reliability assessments. The report recognizes the fundamental shifts taking place in the power industry and echoes a finding from the DOE 20% wind study, which is that there are no fundamental technical barriers preventing us from acquiring 20% of our electric energy from wind resources but that such a change will not be achieved under business-as-usual conditions.

The report includes a background section on the characteristics of variable resources in relation to their power system behavior and discusses the impact of variable resources on the grid in two chapters devoted to planning and operations. The report provides a set of 13 conclusions and recommendations for further work to NERC's planning and operating committees, and it offers a further set of recommended actions for industry in eight areas. A fundamental theme underpinning the report is the recognition that a significant expansion of the transmission system is required to be able to achieve this scenario. The report recognizes the key characteristics of increased uncertainty and variability associated with variable generation. It also recognizes the critically important forecasting tools necessary to deal with this uncertainty and the additional sources of flexibility in the power system necessary to deal with the increased variability.

Some of the report's specific recommendations in the planning area deal with the need for probabilistic tools and techniques for transmission planning, determination of capacity value, and resource adequacy. Additional planning needs identified include the need for standard generic wind plant models for transmission planning software, the need to examine demand response and storage as additional sources of system flexibility, and the need for greater attention to variable resources in the planning process. In the operating area, specific mention is made of incorporating forecasting techniques into operating practices and examining the potential of larger balancing areas and shorter scheduling intervals to better manage increased levels of variability. Additional recommendations point out the need for a review of interconnection standards, including disparities between Federal Energy Regulatory Commission (FERC) Order 661-A and the IEEE 1547 standard, the need for improved communications between wind plants and system operating centers, and the need for a reference manual for planning and operating personnel.

One of the very interesting observations about the recommendations from the IVGTF is the fact there are so many

points of intersection between the needs identified for future work by NERC and industry and the recent efforts that have been made with reference to these topics within PES. This subject will be explored in depth in this issue's first article, on PES's wind power activities. The full NERC report is available at http://www.nerc.com/files/IVGTF_Report_041609.pdf.

Digest of the Articles

We have another great selection of topics and authors to cover the waterfront on wind interconnection and integration this year. The layout is a little different from the past two special issues, in that there is more activity within IEEE, there are larger planning studies under way, and there is more operating experience from around the world. As a result, the emphasis has shifted substantially.

Our first article will deal with the work of the recently created IEEE PES Wind Power Coordinating Committee (WPCC). Dick Piwko, committee chair, leads a team of coauthors very actively involved in these IEEE activities. This should be a big help in understanding what's going on inside the organization and figuring out where you might like to contribute. You will be surprised at the breadth of the activities now taking place.

Our next article provides a review of major wind-integration studies going on in the United States and Europe. The lead author is Dave Corbus from NREL, guiding a team of coauthors directly involved with the studies. You will be amazed at how the scope of the studies has expanded since the study progress report in the last issue. The article covers the two major studies being conducted in the major U.S. interconnections as well as two different studies of the four synchronous systems in Western Europe.

Our third article reviews some of the operating experience with wind plants from North American power systems and points out the importance of wind forecasting on all time scales of system operation. Bill Grant of Xcel Energy is the lead author, with a team of coauthors representing a wide range of operations and forecasting experience from a diverse range of systems. Given the importance of forecasting and the relatively early stage of development for power system applications, we take some time to go into the particulars of forecasting related to the difficult ramping events that cause the most concern for operations personnel. The fourth contribution is a related article from Marc Matsuura of Hawaiian Electric Company (HECO), with an island power system point of view on operations and forecasting.

Our fifth article picks up on the operations theme at the international level and moves from operations into the world of market design and operation. There is a great deal of experience outside of North America from which we can gain some valuable insights and lessons. Thomas Ackermann of Energynautics leads an able team of coauthors representing four countries from Europe, as well as New Zealand. As in the North American article, the field of wind forecasting is quite important and well represented.

Very major developments have taken place in transmission planning in the past two years. These developments have been driven by an examination of the opportunity to move very large blocks of cheap energy from areas of low marginal price to areas of high marginal price. This has opened a lot of eyes to the potential for some very cost-effective high-voltage backbone transmission, first across ERCOT and then across the entire Eastern Interconnection or Western Interconnection. John Lawhorn of the Midwest ISO was the lead writer for our sixth article, on transmission planning, with a very capable team of coauthors representing all three U.S. interconnections.

The seventh and last article deals with a number of popular misconceptions about wind power and power systems, including such topics as capacity value, output variability, backup capacity, energy storage and plug-in hybrid electric vehicles, and the smart grid. The lead author is Michael Milligan of NREL, joined by an outstanding team of coauthors from Europe and the United States. This article deals head-on with a number of often contentious issues, and it is a must-read for everyone.

In Closing

We hope this issue of *IEEE Power & Energy Magazine* will meet your expectations for an informative and lively discussion of the wind-energy issues on the minds of power engineers today. The DOE's 20% report has given us a bit of a target out there and has helped galvanize the thinking about what contribution wind energy can make to the nation's energy supply and its carbon-reduction goals. When FERC holds a technical conference on the integration of renewable energy and the president of NERC says in his keynote address, "The need to reliably integrate renewable resources is no longer a question, it is a priority," I think that we need to take note.

As we have said in this editorial

before, the electric power engineering profession consists of an incredibly talented and dedicated group of individuals

who have created the most complex machine ever devised by man. We imagine the future, and then we build it. We have an amazing opportunity before us, reinventing the electric power system of the future. Let's get on with it!

Acknowledgment

We would acknowledge the vision, encouragement, and support provided by Mel Olken, the editor of *IEEE Power & Energy Magazine*, to help make this issue possible. Working with Mel and with all the authors and coauthors to produce this special topical issue has truly been a pleasure.