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winds of change

issues in utility wind integration

IT IS INDEED AN HONOR AND A pleasure for me to serve as a guest editor, along with Brian Parsons of National Renewable Energy Laboratory (NREL), for this issue of *IEEE Power and Energy Magazine*, which deals with the integration of wind power plants into electric utility systems. I have been in the power engineering profession for 35 years, and I think that wind energy is one of the most exciting and challenging developments to have come along. It's not every day that one gets to be present at and participate in the birth of a technology that has the potential to make a major impact on the way we produce a commodity that is the essential lifeblood of our modern society.

It has been a very rewarding experience over the last 15 years, and especially for the last two years as the executive director of the Utility Wind Interest Group (UWIG), to work closely with so many committed people (both inside and outside the profession) who have had the vision, determination, and energy to turn this development into a commercial reality.

For those not familiar with UWIG, it is a nonprofit association organized in 1989 and incorporated in 1994. Its mission is to accelerate the appropriate integration of wind power into utility systems. We are a technical organization that has focused on identifying and helping to resolve technical issues associated with utility system planning, design, and operation to accommodate significant amounts of wind energy. This includes

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both large wind plants at the bulk transmission system level and single turbines or small clusters of turbines on radial distribution feeders. We began exclusively as a utility association but expanded our membership to now include a broad cross section of industry associated with the manufacturing, design, and development of wind power plants. We work on our technical agenda in close association with the U.S. Department of Energy (DOE)/NREL wind program.

UWIG is at the forefront of dealing with problems that are important to utilities and helping to raise the awareness and understanding of the problems among the interested parties in the hopes of getting them resolved. The interested parties include utility planners and operators, turbine manufacturers, project developers, regional transmission organizations (RTOs) and independent system operators, the North American Electric Reliability Council (NERC) and the Federal Energy Regulatory Commission (FERC), electrical consultants and meteorologists, and the research and development community.

UWIG has been on the leading edge of identifying utility wind integration costs as a major issue and concern that impedes the further addition of wind to the system and initiating work to quantify and resolve the issue. The work, including engineering issues associated with the addition of distributed wind plants on distribution feeders, has expanded and is now ongoing at a broad range of utilities across the United States and around the world.

The most recent issue identified by the industry as needing our concerted attention is that of model development

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and verification for use in the full suite of transmission planning programs. We are engaged with the Dynamic Performance of Wind Generation Task Force of the Power System Dynamic Performance Committee on this issue and look to build and strengthen the relationship between the wind community and the IEEE. The development of the U.S. wind industry has, for the most part, occurred outside of the IEEE Power Engineering Society (PES). As a power engineer who has been an IEEE Member for 35 years, I believe that the IEEE has much to offer the wind community and would like to see a greater degree of interaction and cooperation between the two. I know that there are many others who share this view. The creation of the PES Wind Power Coordinating Committee in San Francisco in June will go a long way in this regard. I hope that this issue of *IEEE Power and Energy Magazine* will help accomplish that objective as well.

How Is Technology Developing?

Wind plants have benefited from steady advances in technology that have been made over the past 15 years. Much of the advance has been made in the components dealing with the utility interface, the electrical machine, the power electronic converter, and the control capability. We have come a long way from the days of the simple induction generator with soft start. We can now control the real and reactive power output of the machine within some design range subject to fuel availability, limit the positive ramp rate of the machine, control voltage, limit power output, and design for low-voltage ride-through. Soon we will be able to provide governor functions and controlled ramp-down during high wind speed events. All of this comes at a price, but it is a quickly moving technology that offers a great deal of capability. It requires understanding the needs of the power system, knowledge of machine capabilities, and applications knowledge of power converter and controls capability to put the entire picture together.

Wind Power Status

The wind industry is young by power systems standards, but it has made great strides in the past 20 years. Wind turbine capacity has grown from 50 kW to production machines of 2–3 MW and more. The unsubsidized cost of energy at the bus bar has dropped by more than 80%, from US$.15–.20/kWh to approximately US$.04–.06/kWh today. Increasing reliability has contributed to the cost decline, with availability of modern machines reaching 97–99%. Other major contributing factors include economies of scale associated with larger rotors, improved energy capture with customized airfoils and variable speed controls, taller towers reaching higher wind speeds, and manufacturing learning curve effects.

At the end of 2004, global wind capacity reached 47,317 MW, with 6,740 MW in the United States. The American Wind Energy Association (AWEA) projects 2,500 MW of new installations this year. On a percentage basis, wind energy is the fastest growing energy technology in the world, logging an impressive 20% annual growth for the past five years. Industry projections are that U.S. capacity could reach 100 GW by 2020, meeting 6% of electric needs, roughly the same share as hydropower.

Deployment is being driven by cost competitiveness, increasing concern about high natural gas prices and volatility, and public policy goals reflected by state renewable portfolio standards (RPS) requiring a percentage of electric generation to come from renewable sources. By January 2005, 18 states had an RPS, with three to five additional states likely to add to that number in 2005. Wind expansion has been aided by a production tax credit (PTC), which, on a 30-year levelized basis, reduces the bus bar cost by about US$.01/kWh. Although there is broad political support for this credit, which is intended to compensate to some degree for subsidies enjoyed by other major energy sources, the PTC has been available erratically over the past several years, hampering orderly growth.

The attractiveness of the wind business is being increasingly recognized by established, diverse energy and utility companies. Two of the largest U.S. developers and owners, FPL Energy and PPM Energy, are unregulated subsidiaries of utility holding companies. AES Corporation recently acquired long-time wind developer/operator SeaWest Wind Power. Goldman Sachs acquired another significant developer, Zilkha Renewable Energy, and the electrical equipment supplier Siemens acquired the Danish turbine supplier Bonus. Since its acquisition of Enron Wind, GE has become the largest wind turbine supplier in the United States. These and other similar actions add new capital and capabilities to the burgeoning industry and illustrate that wind is moving into the mainstream of generation sources.

FERC Rules Getting Updated

The technology advances are taking place in a quickly changing regulatory environment. FERC is dealing with an important set of issues that will have a significant impact on the future of wind integration, thus providing a regulatory backdrop for activities taking place in the commercial marketplace. Many power engineers have not dealt with FERC in the past; that was the province of lawyers. Things have changed recently with the prominence of wind issues on the national agenda.

In late 2004 and early 2005, FERC held three technical conferences related to wind energy. The first dealt with the issues of reactive power control, low voltage ride-through, and communication and control capability for wind plants as a result of the AWEA grid code filing; it resulted in a grid code notice of proposed rulemaking (NOPR). The second was an open forum that focused on market rule changes to enable wind to better compete in wholesale electricity markets. This conference also resulted in a NOPR, this one dealing with the reduction of imbalance penalties for deviations from scheduled wind energy deliveries in return for providing a short-term wind plant output forecast. This is a very critical issue for non-RTO areas operating under the FERC Order No. 888 tariff. The third conference was devoted to an examination of alternative transmission products that could allow the use of transmission capacity that may be contractually committed but physically unused. This is described as a flexible-firm product, which would require modifications to the existing tariff language. Both BPA and PacifiCorp are pursuing this alternative.

And So Are the NERC Rules

We are in a time of transition now with regard to some time-honored utility terms, like control area and CPS2. We are all having a hard time getting used to saying "balancing area and balancing authority (BA)," but we are getting there slowly but surely. NERC has taken note of the changing industry structure with its new functional model and new vocabulary, and it is now taking note of wind developments. NERC created a wind energy task force; it represents a broad cross section of industry and includes a UWIG representative. NERC recognizes that grid codes will deal with issues of reliability and believes that it has something to say about reliability standards for the electric power system. The task force is charged with examining existing NERC reliability standards for applicability to the issues dealing with wind generation and reporting back on additions or modifications that need to be made to standards to deal with specific wind-related issues. As an example, the low-voltage ride-through issue has been identified as one that may be in this category.

Grid Codes Around the World

The United States is not the only country dealing with developing or modifying interconnection rules and processes through a grid code. In fact, in Germany, the issue of low-voltage ride-through was responsible for the grid operator E.ON Netz proposing changes to its code in 2003. Many other countries in Europe and other parts of the world have taken up the issue and have built on the work of E.ON.

Special Features in This Issue

There are five articles presented in this special issue on wind integration, each coauthored by a team of specialists in the field. The articles deal with various topics, such as the physical interconnection considerations of grid codes and models in the article "Making Connections," with Robert Zavadil of EnerNex Corporation as lead author, and the status of operating impact and capacity value investigations in the article "Wind Plant Integration" by lead author Edgar A. DeMeo of Renewable Energy Consulting Services. Richard Piwko of GE

Energy led the writing team of the article “Wind Energy Delivery Issues.” A look at what’s in store for the future is in “The Future of Wind Forecasting and Utility Operations” by lead author Mark Ahlstrom of WindLogics. An international perspective from specialists who deal with high penetrations of wind power on their national systems in Europe is discussed in “System Operation with High Wind Penetration” by lead author Peter Børre Eriksen from Eltra in Denmark.

Look at It in Terms of N-1 Criteria

An issue often raised is what happens if the wind stops blowing everywhere simultaneously and the output of all of the wind plants ceases. How would such a large loss of generation be handled? The application of meso-scale wind forecasting techniques has shed a great deal of light on this question in the past two years. We now know that there is a significant benefit to geographic dispersion because wind patterns vary considerably over large geographic regions, resulting in significant benefits in the dispersion of the wind turbines and their aggregation. This aggregation provides substantial smoothing of the output, especially in shorter timescales, while the dispersion provides smoothing in longer time frames. The wind is always blowing somewhere!

The recent study performed by GE for the New York Independent System Operator provides a good example of this point. The study investigated a 10% wind penetration scenario: about 3,300 MW of nameplate wind capacity on a 33,000-MW peak load system. The capacity was located across the state at 30 different locations. There was no credible single contingency that led to the loss of all capacity in the state. The system is already designed to handle a single contingency of the loss of 1,200 MW, and there was no need to revise that planning criterion. This study, along with grid code and wind plant modeling issues, is discussed further in Zavadil et al.

New Challenges of Variable Output

Another concern often heard about wind power from knowledgeable professionals is what to do about the fact that because wind doesn’t blow all the time, one cannot count on wind power being available when needed. This is a valid concern and should be raised by those who are charged with the responsibility of designing a reliable power system that meets conventional loss of load probability (LOLP) expectations of one day in ten years. As a profession, we have built up a substantial body of knowledge over the past 50 years dealing with that question. A prime example that could be cited is Roy Billington’s work on probabilistic reliability methods.

Given adequate data, the contribution of a wind plant to system reliability, in the form of effective load carrying capability (ELCC), can be adequately calculated. Quite often, the wind plant output is significantly out of phase with the daily load shape, and in that case, there is only a small contribution to reliability. Once known and accepted, the system planning task of designing a reliable system, factoring in the contribution of the wind plant to system reliability, may be readily performed. Indeed a wind plant is generally an energy resource not a capacity resource. We live in a capacity world, and we have to think about a wind plant differently. It supplies cheap energy when it is available, and it is a valuable contribution to a well-designed system.

A number of investigators have pointed out that a wind plant should be viewed as an unconventional form of generation, in an unconventional way, as load (negative load, that is, and not generation). An examination of the statistics of wind production shows that it behaves much more like load than generation. Instead of talking about firming up the wind to make it look like something that it is not, accept it for what it is and deal with the net load accordingly. We're used to dealing with the aggregate load, which has a large degree of random behavior and uncertainty, so let's begin to think about dealing with this new net load in the same way. We don't try to balance each load on the system, so let's not try to balance each wind generator on the system. It is the net system load that's important.

We also have to consider the evolution of the generation capacity mix in a future where there is a growing fraction of wind energy. Several studies have shown that simple cycle gas turbines with very low capacity factor are an economic complement to wind plants from a system point of view. The questions of capacity value, integration costs, and future generation mix are addressed in greater detail in DeMeo et al.

How to Handle Variability

Recent integration studies have shown the benefits of having a deep, liquid, well-functioning spot market in which to conduct financial settlements of deviations from wind plant output forecasts. It is the system that needs to be balanced not every component of the system. At penetration levels of 10–20%, measured by the ratio of wind capacity to peak load within some boundary, there is usually a small but measurable increase in the ramping requirement of the balancing area that can be met by existing generation. At penetrations pushing 30%, the more serious problem that appears is minimum load at light load conditions when a strong wind is blowing. Even without wind plants, utilities sometimes run into minimum load problems on baseload units that must be available to serve the next day's load. This problem can be aggravated by the presence of wind plants and can lead to the need for wind plant curtailment in some circumstances. Alternatively, it can be addressed through the addition of price-responsive load and more flexible generation in the future. This situation is another example of the need for energy markets spanning broad geographical regions and providing increased flexibility in operating the system.

A more natural barrier defining the geographical limits over which systems can be balanced and operated is transmission constraints, which limit the ability to provide ancillary services and scheduling flexibility to resources within the constrained area. Issues associated with transmission planning and market operations are reviewed in Piwko et al.

Control Area Implications

With the transition from control area to balancing area (BA) and control area operators to BAs having been made, we note that some concern has been expressed by small BAs facing the location of a sizable wind plant in their balancing areas. The concern is how it will affect control performance, particularly CPS2. When that is solved, they may then have to forget about CPS2 and look into the BA area limit (BAAL) if there is a new balancing standard.

But the issue remains how to maintain system balance. When I recently asked this question of a system operator, I got a surprising answer. He said perhaps we should start thinking about consolidating small balancing areas so we could afford to concentrate our resources on larger balancing areas with more modern hardware and software facilities along with better training for the personnel having that responsibility. I thought that was an insightful response, and it was exactly what happened in the Electric Reliability Council of Texas (ERCOT) when they went from multiple control areas to one. Imagine what would have happened to CPS2 for West Texas Utilities with the McCamey wind plants, which total about 750 MW. It would have been nearly impossible to balance such a small control area with the generation resources they had available. But, with a stroke of the pen, the boundaries were redrawn, the balancing problem was solved, and new transmission is being built to solve the congestion problem.

Additional studies of how to better manage the system operation through the integration of improved wind forecasting techniques in the operations planning process are underway. These issues are explored in detail in Ahlstrom et al.

Put Energy into Solving Problems

Much energy from many people is going into the discussion of handling the growing presence of wind plants on power systems. A host of issues are up for discussion: how to handle new interconnection requirements; how to handle changes in the planning process; how to cope with the need for new transmission; how to calculate additional costs and benefits associated with wind energy; what, if any, changes need be made in operating practices; what technology developments can better manage the process of change; and what rules need changing so wind generators are not disadvantaged in a system designed for fossil generators. So far, good progress has been made, and a significant body of operating experience is being developed. We can look to the pioneers in Germany, Spain, Denmark, and Ireland for some early guidance and lessons, as further described in Eriksen et al. In the United States, the can-do attitude exhibited by ERCOT, California Independent System Operator, and Xcel Energy, three of the pioneers in integrating wind into their systems, continues to be a source of inspiration for the rest of us as well as providing some valuable experience and lessons.

Involvement with the IEEE

The creation of the Wind Power Coordinating Committee within the PES Technical Committee structure has provided a unique internal structure to engage the many interests of the wind and power engineering communities. The issues with which we are dealing cut across nearly every committee within PES, just as they cut across all areas of utility system design, planning, and operations. Technology and industry are moving at such a rapid rate that new information is becoming available and important decisions are being made that affect our work literally the week or the day before an IEEE meeting. It is difficult to submit a written paper for a panel session dealing with a current topic of interest for wind energy six months before the PES meeting, when new information may be forthcoming right up until the meeting. We must recognize that we are living life in the fast lane when it comes to advances in wind regulatory policy, technology, and business and make adjustments accordingly. Our business practices need to align with the new reality of the real world to provide the service required by our members; we all need the flexibility to be flexible!

The Most Complex System in the World

It has been said many times that the electric power system is the most complex machine ever devised by man, more complex even than the manned space flight program. The design and operation of such a machine could only be carried out by an incredibly talented, capable, intelligent group of people. That group is the long list of scientists, engineers, technicians, mathematicians, computer scientists, and other people who have dedicated their lives to the development, care, and feeding of this machine. I submit that this group is still the most creative, talented, intelligent, and dedicated group of professionals in the world. We have been faced with challenges and problems throughout the history of our industry, and we have always risen to the occasion, solved the problems, and moved on. I have every reason to believe that we will continue to do the same.

New Day Dawning

Wind generation is the fastest growing source of energy worldwide. For many of us, this has created the necessity of a fundamental realignment in our thinking. We must understand all the implications of this and go about the business of helping to create the future. There is a wealth of experience available in every corner of the industry to deal with the issues created by wind energy, and I look forward to hearing from you and working with you to identify and address them. The right combination of new technology, new rules, adequate investment, and positive attitudes will get the job done. Of that I am certain. And I look forward to working with all of you to accomplish it.

I would like to acknowledge the help, encouragement, and support of the editor in chief of *IEEE Power & Energy Magazine*, Mel Olken, in putting this special issue on utility wind integration together. Mel provided the guidance, vision, and leadership necessary to get the issue off the ground and to see it through to completion. p&e