POINT OF VIEW

# Wind Power: Present Realities and Future Possibilities

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In the fall of 2008, the U.S. surpassed 20 000 MW of installed wind power capacity. We have installed as much wind capacity in the last two years as we did in the previous two decades. The U.S. Department of Energy released a report in the spring 2008 titled, "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply." There is a certain sense of optimism and excitement associated with this technology that has not been seen in the electric power business for quite a while. What's going on?

## I. ECONOMICS AND POLICIES

The roots of the modern electricity-producing wind turbine can be traced back 100 years to northern Europe, but we will begin with the California experience in the early 1980s, where a combination of federal and state tax incentives and Standard Offer contracts created a favorable climate for some early wind turbine development and implementation. California was a world leader in installed wind plant capacity through the 1980s and into the early 1990s, but lost its lead to Europe by the mid-1990s. The cost of wind power in the United States was above the market cost of alternative sources of energy, and the technology failed to attract significant investment. During that time, there continued to be a federal wind power R&D program, started after the oil embargo of 1973, which supported fundamental science and basic engineering and contributed to steady progress in technology development. A number of smaller companies continued to pursue the technology, but the leading companies in the field emerged in Europe, particularly in Denmark, Germany, and Spain.

By the turn of the century, wind power had become a permanent part of the European landscape, driven by a stable and favorable policy environment, consisting of strong R&D support through the programs of the European Union and national governments, and the favorable feed-in tariffs in place in Denmark, Germany, and later in Spain. This policy environment has lead to an installed wind capacity of about 65 000 MW in Europe today, out of a world total in excess of 100 000 MW. Development in the United States continued to be driven more by economics than by policy, although a federal production tax credit (PTC) of 1.5 cents per kwh, indexed to inflation, has provided a critical stimulus to the industry. The problem with the PTC was that it was an on-again off-again stimulus, which expired every two years, often reauthorized months after it had expired, and was insufficient to stimulate corporate America to invest in the technology for the long term. As a consequence, there is only one U.S. company in the top ten global wind turbine equipment suppliers today.

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I believe that the ultimate success of wind energy will be determined by a combination of its technical and economic characteristics and how well it is understood and accepted by the electric power industry of the nation. A dramatic cost reduction took place between the early 1980s in California and a few years ago. The technology advances saw the cost of wind energy drop by an order of magnitude, from around 40 cents/kwh to about 4 cents/kwh, and then start to rise again in the middle of this decade with the increased commodity prices and improved operating margins, to an unsubsidized cost of 6–8 cents/kwh today.

## II. CHALLENGES AND SOLUTIONS

In the early California days, power system operators viewed a wind plant as a nuisance more often than not, and required that the wind plant trip off the system during a disturbance and stay off until the system had stabilized and returned to a normal state. With the increasing penetration of wind power today, and especially with the European experience, it is recognized that wind plants need to stay connected during a system disturbance and contribute to maintaining system stability. Grid codes developed around the world now recognize this fact and are making incremental demands on wind plant performance as time goes on.

Wind plants are different from conventional generation plants in that their fuel supply is neither steady nor controllable, and as a result they exhibit greater uncertainty and variability in their output. But the current power system also exhibits uncertainty and variability in both the loads and the generation sources, so it is a difference in degree only. At small levels of wind penetration, the impacts are quite small, but as penetration increases, you can get to the point where the variability and uncertainty are larger than what is already experienced today.

### A. Forecasting

The way system operators deal with uncertainty is with forecasting. In the past, load forecasting was the primary challenge, but now to that must be added wind plant output forecasting. Actually, wind plant output forecasts are pretty good, and the real challenge is to get them into use in the operations and control centers. Numerous studies have shown that about 80% of the value of a perfect forecast can be achieved with state-of-the-art forecasts.

### B. Increased Flexibility

In order to manage the increased variability inherent in the wind plant output, power systems need to increase the amount of flexibility available to the system operators. Flexibility comes from many different sources: thermal generation with fast start, fast ramping, low minimum load, and multiple daily start capability; hydro generation, with its fast start, fast ramping, and sometimes limited storage capability; markets of all types, day ahead, hour ahead, real time, ancillary service; interruptible load and price responsive load; gas storage, and other forms of energy storage like compressed air and pumped hydro. You might think of the sources of flexibility as making up a flexibility supply curve, with increasing amounts of flexibility available for a higher price as you move up the curve. Additional sources of flexibility are found in large balancing areas and large market footprints. They are very beneficial in integrating large amounts of wind energy because of their ability to aggregate wind plants and smooth output variations over a large geographical region, and the very diverse range of resources from which large markets draw.

### C. Control Technology

The interconnected behavior of wind power plants on the electric system is a source of much misunderstanding and concern, as old myths die hard. In the early California days, wind plants were unable to control either their real or their reactive power output, which presented a number of challenges to system operators. Since that time, steady progress has been made with subsequent generations of technology. Today, wind turbine and wind plant control technology is available to provide equivalent or superior performance to that available from conventional synchronous machines in thermal and hydro plants. This is achieved through pitch-controlled variable speed machines with doubly fed asynchronous generators, or induction or synchronous machines with full output converters. With the use of vector controls, very fast response is possible, which can lead to improved stability behavior compared to synchronous machines. In addition, both inertial response and frequency responsive governor behavior can be provided. Fast voltage control is already being provided, similar to a static var system, and the ability to provide no-load vars with the converter while the machine is disconnected has also been demonstrated. Down-regulation can be achieved by spilling wind whenever the machine is operating, while up-regulation can only be provided if the machine is already spilling wind by operating below its available output. This is an expensive mode of operation and should only be used when economically justified.

## III. INCREASED CAPABILITY AND UTILIZATION

There is a creative tension that exists between the wind turbine manufacturers and the grid operators over the performance capabilities of wind turbines and wind plants compared to the expectations set by the performance of conventional controllable equipment. In my opinion, all parties will be better served if more capability is built into the wind plants sooner rather than later. One need only to look at the retroactive additions to grid codes dealing with low voltage ride-through and reactive power control taking place in Europe. The amount of wind capacity that can be added without subjecting the grid to reliability concerns or the wind plants to curtailment can be greatly increased if the wind plants are able to provide both real and reactive control services to the grid, along with the ancillary services mentioned above. I believe we will continue to see a strengthening of the grid codes around the world as technology advances continue and wind capacity increases. The improved response and control features will allow for a much increased wind capacity in the future, and will avoid artificial limits' being imposed in the meantime. Similar performance requirements should be applied to all generators.

A common precondition to achieving the increased utilization of wind energy in our society is a greatly expanded transmission network. The transmission solutions necessary for moving large amounts of energy over long distances are different from the solutions we have employed to provide adequate transmission capacity to meet peak loads in the past. A high-voltage interstate transmission network will be necessary to economically and reliably move large blocks of variable output renewable energy from remote regions to load centers. In addition to transmission, large, deep, liquid, well-functioning, and well-regulated markets will be necessary to deal with large amounts of variable generation over large geographic regions.

It is essential that customer demand be able to participate in the markets, as it offers another significant source of flexibility. An interesting source of customer demand and energy storage that holds great promise for the future is plug hybrid electric vehicles, which can be recharged with electricity as well as with a gas engine. Utility control of the charging process not only offers another source of flexibility to the system at small incremental cost but also provides an opportunity to displace imported gasoline with renewable energy. By introducing electricity into the transportation sector, we not only decrease our dependence on oil imports but also provide a load for wind energy, which is often produced during off peak hours.

## IV. CONCLUSION

In summary, I would say that the world is in the midst of an epochal transition from an unsustainable energy path to a renewable energy path. We are always more comfortable with the devil we know than the devil we don't. There is a tremendous amount of inertia in the system, and the change will not come easily or quickly. But we are on the road to change, and we have little choice but to follow that road and to see where it leads. At the same time, we have a responsibility to help build that road and guide it in the proper direction. I expect that by 2030, 20% will look pretty modest in retrospect. ■