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Technology Advances In Site Assessment

GIS and other tools are now available for wind prospectors.

BY BRUCE BAILEY

High-tech in the wind energy industry applies to more than just wind turbines. In recent years, the specialization of siting and resource assessment has adopted new software and hardware tools to more quickly identify and qualify promising sites, even across extensive geographic areas.

Expanding markets for wind development around the world are sharply increasing the competition among project developers, thereby placing higher demands for more efficient and dependable siting processes. Avoiding prospecting activities in areas that turn out to be disappointing saves development costs and time. And acquiring the best sites first gives the savvy developer the strategic advantage.

New software tools for siting and resource assessment include geographical information systems (GIS) and wind maps. These tools are relatively new to the wind industry but have been around for years in very different applications in other disciplines. The advent of affordable and powerful computing systems makes these tools feasible for applications in the wind industry, where massive databases must be massaged to accurately simulate siting decisions and wind flow behavior.

New hardware tools include remote sensing devices, such as sodar, that act as virtual towers to measure wind conditions at heights where modern wind turbines operate but meteorological masts rarely reach.

Geographical information systems

The most widely accepted definition of GIS is a system of hardware, software and users that manage, analyze and display geographically referenced data. GIS essentially takes features such as roads, parks, elevation contours and cities that one might see on a topographic map and converts each feature into a separate digital layer. Each layer is then linked to a database that can store a limitless number of attributes describing the feature.

An example of this is a demographics database representing counties: various layers can contain information such as population density, land use, land cover, property boundaries and tax assessments, to name a few. The analyst can use the data associated with one layer and look at its relationship to other layers using geography as the basis for comparison.

GIS has proven to be a valuable tool in the wind energy industry. It gives developers and engineers the ability to gather, process and display information necessary for all stages of wind project development. Many types of GIS software are used in the wind industry, some of which are so specialized that they do not wear the GIS title. These include programs such as WindMap, WindPro, WindFarmer and WaSP, all of which use spatial data to produce wind resource grids, optimize wind farm layouts or estimate energy production.

> *Customized applications now allow GIS to be brought into the field with a live link to a global positioning system.*

Software programs such as Environmental Systems Research Institute's ArcGIS suite of software, though not specifically designed for the wind industry, open the door to a world of decision-making that can be tailored specifically for wind plant siting and planning. A very sophisticated way to do this is to combine a number of "what if" siting scenarios with sets of geophysical, engineering and economic databases to identify the most viable candidate development sites within any given target area.

The GIS can be programmed to reveal only those locations that, for example:

• have a minimum annual average wind speed of 8 m/s at an 80m hub height;
• are within 10 km of a transmission line;
• exclude public lands, parks or wildlife habitats;
• contain no slopes greater than 20%;
• are within 5 km of a public road;
• are no closer than 3 km to a residential community, and
• are large enough to support a 50 MW or larger project.

The number of criteria that can be considered is virtually limitless. Results can be displayed in 2-D or 3-D imagery, expressed in terms of capacity factors or levelized cost of energy, and in any of a number of other ways.

The use of GIS is not just for the professional analyst; it can be a powerful tool for many practitioners within the industry. User-friendly GIS applications are now available on a growing number of Web sites that disseminate geographic wind information in the form of wind maps. The maps can be zoomed, navigated, displayed and printed with any combination of data layers by users having no background in GIS. Customized applications now allow GIS to be brought into the field with a live link to a global positioning system (GPS).

Photo courtesy of AWS Truewind

The live GPS link allows users to see their position on a map or aerial photo while in the field, where they can query environmental, transmission line, or any other data that may impact decisions on siting and wind farm layout. Conversely, the skilled GIS practitioner can virtually bring a site to the desktop and, at times, replace the need for field visits, thus saving time and money.

Wind maps

Digital wind resource maps are an essential component of a wind industry GIS database and have become more widely available. Public maps of states, provinces and even whole countries have been produced in recent years, while developers are increasingly commissioning proprietary wind maps, usually for much smaller focus areas where one or more wind projects are being considered.

Wind maps are produced by running atmospheric flow models and combining the results with a GIS to display wind resource information together with other relevant siting information. The most advanced models are full-scale atmospheric weather models that solve physical equations for key boundary layer and other atmospheric processes. For input, they use historical surface and upper atmospheric data, together with terrain, land type, surface roughness, vegetation and other surface defining databases (such as water temperature and soil moisture).

When run at spatial resolutions on the order of a few kilometers or less, they can accurately predict localized winds such as sea breezes, low-level jets and downslope flows that simpler models miss. Higher-resolution models can even capture microscale wind flow influences within a given wind project area imposed by local slope changes, tree lines and buildings.

Running large numerical weather models creates great computational demands. Parallel processing systems or mainframe computers are needed to deliver results within a few days or weeks of CPU time, depending on the size of the domain and the spatial resolution at which the model is run. The higher the resolution, the higher the accuracy achieved when predicting wind conditions, especially in complex terrain and near land-water interfaces.

Wind speed prediction errors have fallen by 50% to 75%, compared to modeling techniques used 15 years ago. Standard errors exhibited today are typically in the range of 5% to 8% at hub height when compared to on-site wind measurements extrapolated from meteorological masts. Although wind mapping alone is not enough to plan, finance and build a wind project, it can substantially reduce the time and risks of site selection compared to traditional methods. Wind flow models also provide the means to accurately interpolate the wind resource between existing meteorological towers.

Sodar – sonic detection and ranging

When the site assessment process advances to the level of wind monitoring, meteorological towers are installed at one or more locations within a project area to help define and verify the on-site wind resource. However, the heights of meteorological towers have not kept pace with the rise in turbine hub heights. Whereas hub heights of most new wind plants are in the range of 65m to 80m, conventional tilt-up type meteorological towers reach only to heights of 40m to 60m.

Estimation techniques must then be used to predict the wind resource at hub height. This introduces an unwelcome source of uncertainty and financial risk when predicting the output of a wind turbine whose rotor blades are capturing wind energy at heights of 100m or more above the ground. Wind shear profiles can be significantly different within this elevated layer of the atmosphere compared to lower levels where most meteorological towers are sampling.

To overcome this situation, taller lattice-type meteorological towers could be installed, but at a cost five to eight times greater than shorter, tilt-up types. Taller towers are also more likely to be difficult to permit and more likely to require aviation obstruction lighting systems. Consequently, alternative approaches to determining hub height wind conditions are in demand. Ground-based remote sensing tools, such as sodar, offer an attractive alternative to tall towers.

Sodar (sonic detection and ranging) is a portable acoustic technology that can be easily deployed to accurately measure the boundary layer's wind profile and turbulence structure at heights of at least 150m.

Sodar is a decades-old technology and is a recognized technique in EPA air-quality monitoring programs, but it has yet to be widely used in North America by the wind energy industry. Significant technology advancements have been made over the last decade, with instruments having become more portable, robust and reliable. Sodars cost between $30,000 and $50,000, which includes options for independent power supplies and road-worthy trailer containers.

Sodar works by emitting pulses of sound (or "chirps") upward into the atmosphere and analyzing the echoes generated by the small-scale temperature fluctuations associated with atmospheric turbulence. The echoes are shifted in frequency due to the Doppler effect. By analyzing the timing and the frequency shift of the return echoes, the sodar derives the vertical profile of the wind speed and direction.

This profile is normally defined in 5m to 10m intervals of height above the ground. Phased-array sodars permit determination of the three components of the wind velocity – the vertical velocity and the two horizontal components – by steering the acoustic beam upward at different angles using phase shifts among the speakers.

Sodar is best used in conjunction with existing "short" meteorological towers to define wind shear conditions above the tower for a wide range of wind speed and direction conditions. Comparisons of wind measurements taken at the same heights from towers and sodar are typically in close agreement (within a few percent), which is quite acceptable given that they are not actually sampling within the same exact space and use fundamentally different measurement approaches.

In some climates, a sodar sampling period as short as three weeks may be sufficient to determine the prevailing wind profile conditions at a site. In other climates where atmospheric stability varies sharply with season, it may be necessary to conduct sodar campaigns two to three times in a year. In either case, sodar offers a stealth alternative to tall towers and reduces the site assessment uncertainties inherent to shorter towers alone.

Future prospecting

Site assessment technologies are steadily becoming smarter and more widely accessible. GIS and wind mapping will benefit from the expanding availability of accurate global geophysical databases and from the steady advancements in affordable computing power. Data from dispersed meteorological and sodar stations across broad regions will be centrally collected and processed by numerical atmospheric models as part of forecasting efforts to schedule wind plant output in the next-hour and day-ahead energy markets.

Wind flow modeling will also improve, as boundary layer processes within 150m of the ground are better understood through the wider use of sodar and other emerging remote sensing technologies, like lidar. Combined, these advancements are making wind project siting and operations more reliable and predictable and will facilitate the spread of cost-effective wind energy throughout the world.

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