FORECASTING OF WIND GENERATION

The wind power of tomorrow on your screen today!

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Leader Text

Either for trading or for power system operation, wind power forecasts have become necessary input to the daily management of wind generation. While fast transfer of research results to operational and commercially available products has been witnessed over the last few years, there still are challenges to face in order for wind power forecasts to fully satisfy the needs of their various users.

Article Text

11:00am, trading floor of DONG Energy, Denmark, operator of significant wind power capacities. The trading team already has all information about availabilities together from the conventional power stations at DONG Energy's disposal. One hour until the gate closure of the day-ahead market on the Nord Pool, the large Nordic electricity exchange, and the European Energy Exchange (EEX) market at Leipzig. Now is the time to consult the latest forecasts for tomorrow's wind power production and load, in order to distribute the expected production on the different electricity exchanges and to obtain an optimum price for it. Same time different location, an operation analyst in the Power Control Center room of Red Eléctrica de España (REE, the Spanish Transmission System Operator, Figure 1), gets another fresh update from the system adequacy tool based on their wind forecasts – and certainly also on solar forecasts in a near future. As usual, the sum of the wind forecasts provided to the market by the wind power operators differs by a few hundred MWs from the in-house forecast. The operation analyst chooses to give his confidence to the in-house one, as this in most cases is known to be better. Simultaneously in Dublin, the grid operator Eirgrid updates yet another time the prognosis, adjusting the amount of ramping capacity for the next six hours to be able to provide the Wind Following Capability needed in the small grid with large amounts of wind power. Three different users of wind power forecasts, three different challenges being addressed by the forecasts. And the list could continue…

A general overview

As objectives of integrating more and more wind power generation into the electricity grid are set, it becomes fairly clear that this will require significant changes in terms of structure and management of the grid. This may take the form of the upgrading of transmission and distribution networks, but may also lead to the redefinition of the way electricity may be exchanged between producers and consumers. The most significant change is certainly that instead of relying on controllable generation sources – in the sense that we can decide in advance which power is to be produced, a significant share of the electricity generation will be imposed by the wind, being far from controllable. Therefore, forecasts of wind power production will have an increasingly significant role in the operation of power systems and in the participation of electricity portfolios in liberalized electricity markets, partly owing to their influence on the market clearing price. Necessary forecasts have different horizon depending on the decision to be made, going from few seconds or minutes ahead for control applications, up to 10-day ahead for optimal maintenance planning. The horizons that attract the most attention range from say 1 hour to 2-day ahead, since they are relevant for the daily operation of the grid, or trading of electricity generation.

The contributors to research developments

Since the first works on wind power forecasting in the beginning of the eighties, research actors have evolved from regarding wind power as a simple application to seeing it as a motivation for new methodological developments. The first operational models used in Denmark in the early 1990ies were using standard approaches, put together from the built-up knowledge of the wind power meteorology or standard statistical approaches which just happened to be applied to wind speed and power data. Nowadays, mainly three categories of researchers concentrate on such methodological developments, coming from the meteorological field, the dynamical statistics one, as well as that of power system engineering. Maybe one of the most significant recent advances on wind power forecasting is hence the more common and intense collaboration between researchers and developers from these seemingly disconnected areas. This collaboration has yielded a large number of fresh ideas, consolidated expertise, and accelerated the transfer of research and development results to the forecast users, regulating authorities and policy makers. This type of collaboration is initiated at the level of single countries, but also at the international level. To our opinion, one of the most successful examples relates to the Anemos consortium, consisting of researchers, software developers, and forecast users. They have concentrated on a varied set of problems related to improvement of forecasting methodologies and technologies, with particular focus on forecast quality, as well as software reliability and user-friendliness.

Figure 1: *The power control center at Red Eléctrica de España (REE) includes an operation unit which manages and control the renewable energy generation for the entire country, called 'Cecre'. [Picture courtesy of REE – www.ree.es]*

The root of recent developments

The need for accurate, commercial, and utility-class forecasting services has been a driver for developments at both the research and operational levels. In parallel the availability of more and more data, such as meteorological measurements and forecasts, power measurements, or satellite images, has opened the door to proposal of new forecasting methodologies. Indeed, when in the past forecasting methods were developed for a single site of interest, based on a minimum set of measurements, newer ones are now able to cope with different spatial resolutions, automatically adapt to the evolution of wind park capacities and maintenance planning, to accommodate multi-source data, or to get the best of multiple forecast by intelligent combination. In addition, it was common few years ago to separate physical and statistical approaches to wind power forecasting, while all state-of-the-art forecasting methods today include a varying share of both. Physics ensures the capture of the medium-term dynamics of the atmosphere, statistics permits calibration to measurements and adaptation to the varying nature of the wind generation process, while they can both be employed for representing the power curve for the conversion of wind to power. A sound combination of the two yields a so-called grey-box approach, where advantage is taken of physical knowledge, while accepting that certain parameters are to be estimated from available data.

The forecast uncertainty issue

Historically, the classical view of wind power forecasting has been a deterministic view: forecasts have mainly taken the form of point forecasts, that is, giving one value of expected power production for each look-ahead time in the future. However, it has appeared that the accuracy of such forecasts may be too low on average, and highly variable depending upon meteorological conditions. A rising demand of forecast users has then been on information about the situation-specific uncertainty of wind power forecasts. This has led to a high number of research works on how to best estimate and also communicate forecast uncertainty. Uncertainty information take the form of either risk indices, telling on the confidence one may have in the provided point forecasts, of fully probabilistic forecasts giving the probabilistic distribution of potential power production for each forecast horizon e.g. Figure 2, or of a set of power production scenarios (Figure 3). Making decisions (in terms of power system operation, trading or maintenance planning) for forecasts and associated uncertainty can be fairly complicated. And this is why today intense collaboration is needed between forecasters and forecast users in order to optimize decision-making.

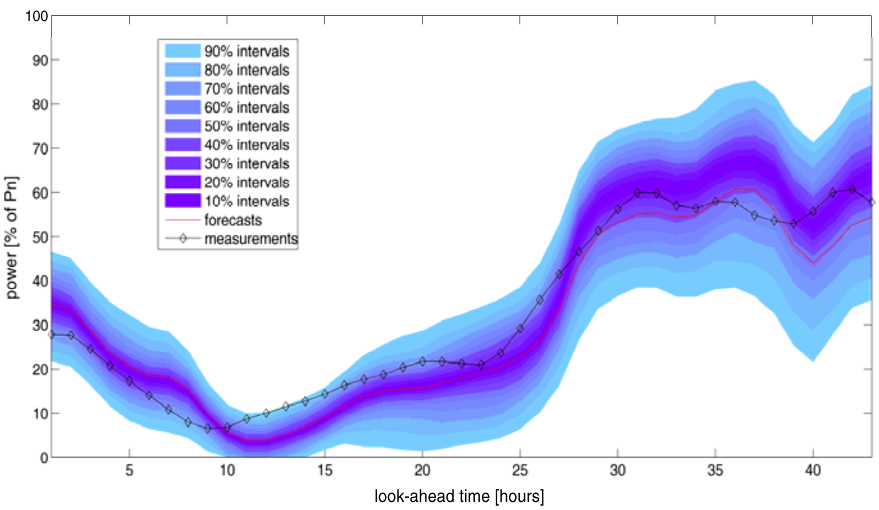

Figure 2: *Example of 2 day-ahead forecasts of wind power for a region in the Northern part of Denmark. These forecasts give both the expected power production and the probability distribution of power production for each look-ahead time.*

On the role of forecast users, regulation authorities and policy makers

The tight relation between forecasts, their uncertainty, and decision-making, has actually led to one of the most profound changes in the approach to forecasting. While still a few years ago forecasters would only focus on maximizing the accuracy of their wind power predictions, they know see that what is also necessary is to optimize the value of such forecasts, that is, the benefits resulting from their use. For a trader, this directly translates to maximizing revenues from participation in the market. In contrast, a transmission system operator may think about this in term of minimization of reserve requirements needed to cope with wind forecast uncertainty. A side effect of such a shift towards maximization of the value of the forecasts will necessarily be a gain of interest of forecast users in improvement of forecasting methodologies, since they will directly resent the benefits from this development. However, as each type of decision-making problem may involve different inputs and different methodologies, the optimal forecast to be used as input may be of different nature. Having a more global view of the wind power forecasting and decision making problems will benefit both forecasters and forecast users.

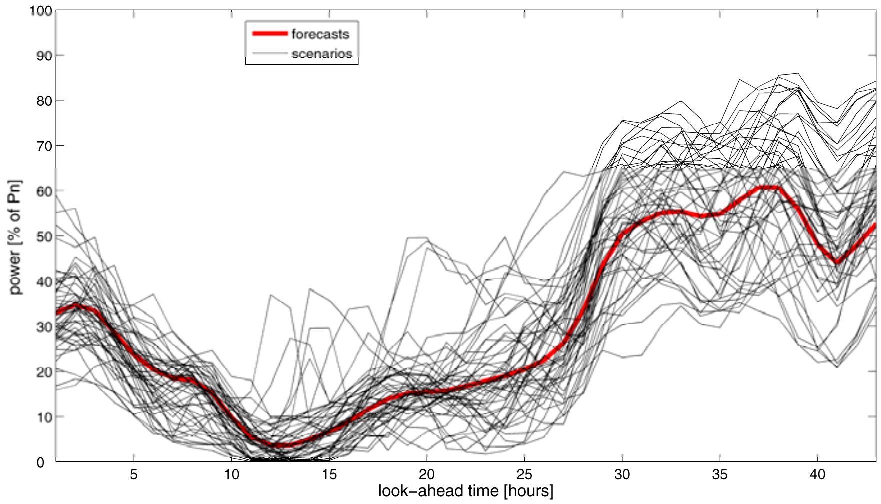

Figure 3: *Example of a set of 2 day-ahead statistical scenarios of wind power production corresponding to the probabilistic forecasts of Figure 2.*

The challenges to come

As mentioned above, more and more data are made available as input to wind power forecasting models. Nearly every new large wind farm has real-time collection and online transmission of (at least) power measurements. Even more data can also be beneficial, though from our experience, it would appear more appropriate to concentrate on having data of higher quality. By this, we need more reliable measurements, the uncertainty of which could be deemed as negligible. The question of the quality of meteorological forecasts used as input to wind power forecasting models is also a crucial one. Different works have shown that the largest share in wind power forecasting errors comes from the input meteorological forecasts. If for instance a timing error is present in the meteorological forecasts, it will be directly passed on to the related wind power forecasts. It should then be envisaged to use several meteorological forecasts as input, with appropriate combination methods allowing getting the best out of those inputs. Fortunately, more data, joint research efforts, and rising commercial interests, will certainly help further acceleration in the improvement of forecast accuracy. In parallel, the case of extreme prediction errors, which are the most costly whoever the end-user is, will necessitate particular attention.

More generally, forecasting of wind generation should be seen in the future as a more global problem. It encompasses meteorological, mathematical, power system and economical aspects which should be given consideration in a cross-disciplinary fashion. It should also be seen as a more global problem in the sense that since the meteorological conditions are the driver for wind generation, the power production for neighboring sites is obviously interdependent. Similarly, forecast errors made at a certain site are somehow related to errors for a neighboring site in a previous or following period. Therefore, potential communication of data between neighboring production sites, or an overall management of such data, have the potential to yield an optimal use of available information, consequently permitting the issuing of warnings for the case of extreme events, global corrections of forecasts for a maximized prediction accuracy, or a safer operation of the grid for the transmission system operator.

A last point certainly relates to approaches to power system management. Forecasts will certainly still be needed in the future since decisions have to be made a certain amount of time in advance. But forecasts will always contain a part of error. Therefore, their use in production planning, trading or other tasks, will include a part of uncertainty. If more and more wind power is to be integrated into the grid, our whole approach to management has to turn towards probabilistic approaches, permitting to account for these uncertainty aspects, for the non-symmetric nature of regulation costs, as well as to control the risk of unbearable costs coming from unforeseen events. This then also means that easing integration of wind generation via the use of forecasts is not only a technical problem: all actors concerned should be aware of probabilistic methods and more sensitive to the concept of risk management. This may happen through research and development actions including both forecasters and forecast users, or by increasing the share of probabilistic methods in the education of our future power system engineers. The environment-friendliness of wind energy has its cost, that of variability and uncertainty, which, with the right tools, can be accommodated.

Biographies

Pierre Pinson is Associate Professor at the Technical University of Denmark. His expertise mainly covers modeling, forecasting and decision-making for the integration of renewable energy generation in markets and power systems. He is involved as principal scientist and coordinates research works in several research projects (e.g. Anemos.plus, POW'WOW, SafeWind) related to wind power forecasting and integration.

Gregor Giebel has worked in wind energy at Risø DTU for over 12 years in the field of short-term forecasting, condition monitoring and large-scale integration of wind energy in the grid. He is now senior scientist. He holds a PhD from Oldenburg University, and is Diplomphysiker from the Technical University of Munich. Amongst many other reports and papers, he authored a 38 page report on the state-of-the-art in short-term forecasting of wind power.

Henrik Madsen is Professor in Statistics with a special focus on Stochastic Dynamic Systems at the Technical University of Denmark. His main research interests are related to analysis and modeling of stochastic dynamics systems, with application to energy systems among others. In parallel, he is the leader of the Center for High Performance Computing at DTU.

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