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DISCUSSION

Comments on: Space-time wind speed forecasting for improved power system dispatch

Pierre Pinson

First, I would like to acknowledge Zhu, Genton, Gu and Xie (ZGGX) for their substantial effort in jointly looking at the problems of improving short-term wind and corresponding power forecasts, and of using these forecasts as input to a relevant decision-making problem. It here involves the least-cost scheduling of conventional generators (economic dispatch) in a power system with substantial wind energy penetration.

Forecasts are to be issued as a basis for decision support: it then appears sound to evaluate whether or not forecast improvements yield benefits to those employing these forecasts as input to decision-making. When it comes to renewable energy (more particularly wind power), forecasting and operational problems have been the focus of considerable research over the last 3 decades, from very few works in the 1980s to tens (if not hundreds) of manuscripts published every year nowadays. While the work of ZGGX is to be seen as a good reference presenting approaches to improved forecasting and integration of forecasts in operational problems, I believe some additional aspects may be discussed here in order to give a more complete picture. These aspects mainly relate to recent advances in renewable energy forecasting and to the use of probabilistic forecasts in operational problems.

1 Advances in renewable energy forecasting

Numerous approaches to wind power forecasting exist today. Most of these approaches have subsequently been adapted and extended for the case of other renewable energy

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P. Pinson (✉)
Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark
e-mail: ppin@elektro.dtu.dk

sources, for instance, solar and wave energy. This can be explained by the similarities in these prediction problems, involving the future evolution of relevant atmospheric and/or oceanic variables, as well as their conversion to electric power through dedicated energy conversion devices, e.g., wind turbines, solar panels and wave energy converters. The fact that more emphasis has been placed on wind energy, so far, can certainly be explained by the predominance of this energy source with respect to other renewable energy alternatives. A good general overview of existing methodologies for wind power forecasting can be found in Giebel et al. (2011), while some of the authors of ZGGX also recently published a more targeted review of the state of the art, focused on statistical models and their application in power system operations Zhu and Genton (2012).

Accounting for spatio-temporal effects in order to improve the quality of wind power forecasting is a possibility that has been explored for the last 15 years, after the original proposal of Alexiadis et al. (1999). In the present manuscript, ZGGX build on the methodology and dataset originally analysed by Gneiting et al. (2006) for the particular setup of the Columbia River Basin in the Pacific Northwest region of the United States of America. Accounting for such effects certainly is easier for cases where some locations are obvious sensors, for instance, owing to thermal breezes and topographic features. In a more general setup where spatio-temporal effects are dynamic and conditional to prevailing weather conditions, more complex approaches may be necessary. In that sense, the proposal of ZGGX comprises an interesting generalization of the Regime-switching Space-Time Diurnal (RSTD) model of Gneiting et al. (2006) by allowing for the defining boundaries of the regimes to be more data-driven and to evolve over time. Another form of generalization would be to consider varying-coefficient models, whose parameters are a function of wind direction, as for the example case of Pinson (2012). A drawback of the varying-coefficient model alternative, however, may come from the increased amount of observations necessary for estimation. On the positive side they require less work and expert knowledge in relation to the definition of regimes. Other regime-based approaches may be thought of, where the regimes can be defined explicitly or implicitly. From a more general point of view, it is not clear which approach may be best, depending upon test case and quantity of data available. In contrast, we know today that the improvement of short-term wind and power forecasts will require new types of observations at high spatial and temporal resolutions, as for the example of X-band and C-band weather radar images (Trombe et al. 2013), as well as dedicated statistical models.

Owing to the complexity of the wind power generation processes, being nonstationary, nonlinear and double-bounded, forecasts will always contain a variable and dynamic part of error. This has motivated a strand of literature concentrating on probabilistic approaches to wind power prediction, aiming at fully informing about future power generation. From an operational point of view, accounting for uncertainty is a real plus that can allow formulating a number of operational problems in a stochastic optimization framework. Probabilistic forecasts may take various forms depending on the type of operational problem at hand, and of its formulation in an optimization framework (Pinson 2013). For instance, quantile forecasts are sufficient for some of the simplest electricity market participation problems, robust optimization formulations of market-clearing mechanisms require interval forecasts (Zugno and Conejo

2013), while the least-cost scheduling of conventional generators cast in a stochastic programming framework calls for scenarios of wind power generation (Papavasiliou and Oren 2013). The forecasting methodology of ZGGX is thought of in a probabilistic framework based on a truncated Normal assumption for the predictive densities of wind speed. The authors then made the choice of which single-valued forecasts should be extracted from predictive densities, more precisely, based on a linear loss function. This has the advantage that resulting point forecasts can be readily used in existing deterministic approaches to economic dispatch. Additional benefits could be obtained by fully utilizing the information contained in the original probabilistic forecasts.

2 Operational problems, quality and value of renewable energy forecasts

Forecasters naturally aim at improving their predictions by enhancing their modelling approaches. For instance, here, ZGGX propose to further account for spatio-temporal correlations in wind observations. Better modelling the physical processes involved does not mean that the predictions will be better, unconditionally. In that vein, Murphy (1993) elegantly explained the difference between forecast *quality* and *value* as two sides of how forecasts may be seen as *better*. They correspond to the views of the forecaster on one side and to those of the forecast user on the other side. Roughly, it boils down to the forecaster and forecast user having different loss functions. A forecaster typically aims at minimizing a quadratic loss function, as if taking part in a forecast competition where the root mean square error would be the lead criterion. In contrast, a forecast user has more varied and complex loss functions in relation to his specific decision-making problem, most likely expressing potential financial gains and losses. Reconciling forecast quality and value is not an easy task. As mentioned in the above, already deciding about which single-valued forecasts to extract from predictive densities relies on a given loss function. For an extensive treatment of these aspects, please see Gneiting (2011) and references therein.

For the economic dispatch problem considered by ZGGX, it could well be that the optimal point forecasts to extract from the truncated Normal predictive densities do not correspond to their median (with nominal level of 0.5). The nominal level of the optimal quantile could be slightly higher, in case it would be less costly (in expectation) to place the power system in a situation where it more likely that wind generation is less than anticipated; or conversely a little bit higher if the opposite situation is preferred. In contrast, one of the advantages from considering probabilistic forecasts as input to decision-making problems formulated in a stochastic optimization framework is that the decision about best single-valued forecasts to extract from predictive densities becomes implicit.

More generally, if not considering spatio-temporal aspects only, I would strongly encourage other authors to follow an approach similar to that of ZGGX, in order to evaluate the operational benefits of forecast improvements for real-world decision-making problems. There exists a wealth of such problems related to renewable energy generation in power systems management and electricity markets still worth looking at. One might then be surprised by the fact that, for some problems, even slight improvements in forecast accuracy could yield substantial operational benefits, while, in other cases, even sizeable forecast improvements have no value for the forecast users.

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