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Stochastic Energy Systems

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### - Variety of approaches and product for probabilistic forecast

## Background :

Probabilistic forecasts of renewable energy generation (especially wind power, since having a leading role in a number of European countries) are becoming increasingly accepted as an optimal input to a number of decision-making problems related to market participation and power systems operations. While from a practical point of view they give a very visual information about forecast uncertainty, they also give a mathematically sound description of the range of possibilities for the coming future in terms of wind power generation. Still a few years ago, only a few approaches to probabilistic forecasting of wind power prediction were described in the scientific and technical literature, while even less were implemented operationally.

Approaches to probabilistic forecasting:

Approaches to probabilistic forecasting generally rely on advanced statistical modelling with or without meteorological ensemble forecasts as input. In the best case probabilistic forecasts are derived based on already issued point predictions, which in turn already accounted for the dynamics of deterministic meteorological forecasts. In parallel to this meteorological information, a wealth of measurements is to be used for data-mining purposes. This can be for clustering weather situations yielding various levels of forecast uncertainty, or in order to better characterize the shape of predictive densities hence representing the asymmetric character of uncertainty and the potential risk of extreme forecast errors. Common outputs of these probabilistic forecasting methodologies are the so-called quantile forecasts, prediction intervals and predictive densities.

A wealth of methods based on different theoretical background and using varied types of information as input were developed and refined through the lifetime of the EU project SafeWind.

And what is the interest of having so many different methods?

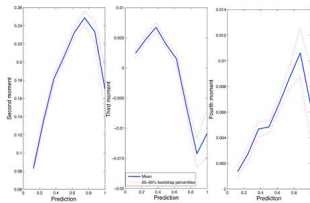


Figure 1: Example investigations related to probabilistic forecasting approaches. Top left: modeling of conditional moments of predictive densities; top right: artificial-intelligence based method to probabilistic forecasting; bottom: investigation of stochastic power curves for the conversion of probabilistic wind forecasts to power

Still a few years ago from a scientific point of view, it was not clear which input data and methodologies were the most appropriate for high-quality probabilistic of wind power generation. In addition since emphasis was placed on extreme events in the EU project SafeWind, it was chosen to look at these methodologies and data with such extremes aspects in mind. The points of focus included investigation of :

- parametric and nonparametric approaches to probabilistic prediction,
- use of deterministic and/or ensemble forecasts as input,

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- statistical and artificial-intelligence based techniques,
- regime-switching aspects,
- verification methods for probabilistic forecasts

Some of these aspects are illustrated in Figure 1.

An example set of nonparametric probabilistic forecasts is depicted in Figure 2. These were produced for the test-case of the whole Western Denmark power systems (also called DK-1), operated by Energinet.dk the Transmission System Operator in Denmark.

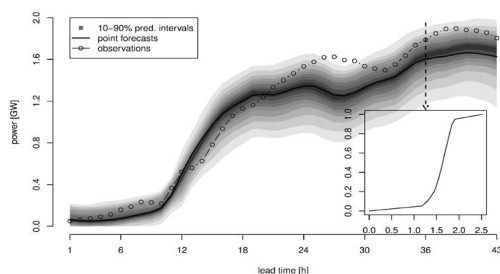


Figure 2: Example 2-day ahead forecasts of wind power generation for Western Denmark issued on the 4th April at 00:00UTC. These take the form of nonparametric predictive densities, which are of high-quality though less informative with respect to extreme forecast errors.

This substantial work allowed to answer a number of questions on the interest of various approaches in view of the forecast users needs.

## Implementation and demonstration of probabilistic forecasting

### **approaches:**

Some of the proposed methodologies were implemented by in the ANEMOS prediction platform and demonstrated for a set of test cases. In parallel the methods were benchmarked offline for a larger number of case studies, the results of which were used as a basis for publications in the scientific and technical literature.

### **Further Work:**

A lot more work is ahead of us when it comes to probabilistic forecasting fo wind power generation, form both methodological and applied point of views. For the case of extreme events, they should concentrated on more robust description of uncertainties with potentially new probabilistic distributions or adaptation of existing ones. Combination of nonparametric and parametric approaches will certainly yield the best results. Finally, new score and diagnostic should be proposed so as to better underline the quality and flaws of competing approaches to probabilistic prediction.

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