Danish Ministry of Climate, Energy and Utilities

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# THE DANISH PERSPECTIVE ON FORECASTING AND INTEGRATION OF RENEWABLES IN POWER SYSTEMS

The forecasting of power production from variable renewable-based technologies is the backbone of any well-functioning power system highly based on renewables. The Danish experience shows, in one of the power systems with the largest share of production from variable renewables (50% in 2019), that a proper approach to forecasting can integrate renewables without compromising the stability of the grid and the operation of the generators. This approach can avoid instances such as curtailment of renewables or the extensive use of batteries and reserves for ancillary services. This fact-sheet illustrates the key learnings from the Danish experience.

## The importance of forecasting

Transmission System Operators (TSOs) are responsible for balancing supply and demand on regional or national grid systems. The increasing share of variable renewable energy (VRE) (wind and solar) in the overall energy mix and the variability on the demand side make this task challenging. To avoid balancing problems and to keep the stability in the grid, TSOs use forecasting tools to predict the demand and VRE generation.

Observations show that wind forecasts are extremely important for effective grid management when the penetration of wind energy exceeds 5 % of the total installed capacity. Inaccuracies in VRE forecasts may lead to increased requirements for spinning reserves and higher electricity production costs. In addition, unforeseen large ramp events can affect the reliability of the power system. Particularly for power systems where the thermal power fleet has short margins for flexibility.

VRE generation forecasts are made for different time horizons: a few hours ahead forecasts ensure efficient and safe use of regulation power and the transmission system; 12-36 hours ahead forecasts ensure efficient trading on a power exchange; and day ahead forecasts ensure optimal operation of large power plants. For example, the Danish TSO Energinet prepares forecasts, for VRE production and electricity demand, for a period ranging from the coming five minutes to ten days ahead.

## Challenges

Power production prognosis from renewable resources, in particular wind and solar, is a challenging task. VRE production forecasts are based on meteorological forecasts for wind speed, temperature, precipitation, humidity and cloud cover. The quality of the forecasts often differs depending on the forecast provider and the applied methodology. Even small inaccuracies in weather forecasts may lead to large errors in energy production forecasts.

For instance, in a power system with more than 5 GW installed wind capacity, a change of 1 m/s in wind speed can cause a change of more than 500 MW in power production. If the power system is not flexible enough, such large change in power production can lead to grid congestion, wind power curtailment and imbalances.

Errors in forecasting often increase with longer forecasting horizon, limited data availability and poor data quality, distorting the optimal dispatch, balancing and reserve requirements. Although high quality data and shorter term forecasting horizons decrease the margins of the forecasting errors, the system operator should have both a trained staff and an efficient operational planning system, to make the best use of the VRE production forecasts and take the required actions.

## The Danish experience

Based on accurate forecast systems, the Danish TSO Energinet currently operates a power system with an average of 50% production from fluctuating renewables (2019). Forecasts about production, scheduling and international transmissions are considered altogether, to satisfy consumption while maintaining the balance in the power system.

The Danish power system is characterized by a substantial penetration of renewables, especially wind power, thus making essential wind forecasting for operational planning. Due to the uncertainties associated with the stochastic nature of the weather, the Danish TSO uses multiple internal and external wind forecasting tools. The forecasts are in five minute resolution and are updated every few minutes using all the latest information available. They cover both the short term horizon used for operating the grid in real-time as well as the day(s) ahead horizon used for planning purposes.

The forecasting tool uses pre-trained power curves and considers various inputs (e.g. wind speed, wind direction, real-time production data, geo-reference) to provide a spatio-temporal based forecast for wind power production. A combination of different meteorological forecasts is paramount as different forecasts imply different expected wind speed, which can lead to consistent challenges in terms of power production. The Danish TSO currently uses three different weather forecasts, based on global and local forecasting accuracy. The forecasts are correlated with actual measured data, to calibrate the models and reduce predictive errors. Hereby the errors are reduced to a level whereby it can easily be covered by the reserves.

The high quality of energy forecasting allows to smoothly integrate large quantity of wind production in the Danish power system and planning well-ahead balancing and reserves' needs. A proactive planning and balancing approach such as the Danish one, where the forecast is used to predict the imbalance before it appears, allows the TSO to handle any imbalance with slower/cheaper reserves compared for instance with reactive balancing.

**The strengths of the Danish forecasting approach thus rely on:**

- Collection of geo-accurate historical data on VRE plant production, as they are the main backbone for validation and calibration of new forecasts
- Collection of a wealth of weather forecast parameters (e.g. global radiation, wind speed, wind direction), as they allow to improve the weather forecasting tools (a national meteorological institution is recommended)
- Development of geo-accurate weather forecasts, enough to cover the geographical distribution of the (future) RE-production
- Trained and experienced staff, able to understand and deal with the challenges of running a system with variable generation and using the relevant information (forecasts, schedules, measurements,etc.)
- Development of state-of-art forecast models and operational planning tools which, based on the characteristics above, enable a high forecast accuracy of VRE production, load and international transmission.

Besides the production from renewable sources (e.g. wind and solar), the Danish TSO relies on accurate forecasts of electricity demand (consumption), exchange with neighboring area and generation from conventional plants for a secure and efficient operational planning (to operate and plan efficiently) of the power system.

Showcases of the Danish experiences have been used to enhance the development of forecasting systems in an international context. A non-comprehensive review of collaborations includes Ethiopia, Indonesia, India, Mexico, South Africa, Ukraine and Vietnam.

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