Understanding Uncertainty: the difficult move from a deterministic to a probabilistic world

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Forecasting Session 9b
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Background of this investigation:
IEA Task 36: Forecasting for Wind Energy

**Task Objective is to encourage improvements in:**
1) weather prediction
2) power conversion
3) use of forecasts

**Task Organisation is to encourage international collaboration between:**
→ Research organisations and projects
→ Forecast providers
→ Policy Makers
→ End-users and stakeholders

**Task Work is divided into 3 work packages:**
WP1: Weather Prediction Improvements inclusive data assimilation
WP2: Development of a benchmarking platform & best practice guidelines
**WP3: Communication of best practice in the use of wind power forecasts**

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FROM THEORY TO PRACTICE

METHODS FOR GENERATING UNCERTAINTY FORECASTS

APPLICATIONS FOR UNCERTAINTY FORECASTS
   A. Using uncertainty forecasts for situational awareness in the control room

   B. Using uncertainty forecasts for trading and balancing
      Trading Strategies
      Critical Ramps
      High-Speed Shut-down events

   C. Grid Technical Constraints Management

SUMMARY AND OUTLOOK
Methods for generating Uncertainty Forecasts

For details please see:

http://www.ieawindforecasting.dk/publications
APPLICATIONS FOR
UNCERTAINTY FORECASTS
Situational awareness in the Control Room

When forecast is off multiple times:
→ operators lose trust & stop acting when using deterministic information
→ operators keep focus and confidence when using probabilistic information

→ Deterministic methods “hide” uncertainty of forecast
→ Decision making with probabilistic information is always better

→ Type of uncertainty forecast and appropriate communication is crucial
Situational awareness in the Control Room

Single deterministic forecast  versus  a probabilistic forecast

Situational Awareness amongst System operators has become important for those:

- not at all or weakly interconnected
- prone to variable weather conditions and high wind speeds
- penetration levels challenging traditional reserves (>25%)

KNOWING WHAT MAY HAPPEN HELPS PLANNING MORE SAFE AND ECONOMIC!!!
Situational awareness in the Control Room

Making the uncertainty of forecasts visible is:

1) empowering the operators
2) should not be seen as a complication

Providing information to the operator about the trustworthiness of a forecast and possible outliers is exactly what is required to:

- be prepared
- be able to act in good time
- make operations more smooth
- make operations less expensive
- act under less stress

The two most important requirements:
(1) method being used to provide uncertainty indicators
(2) communication of the uncertainty

The pitfalls are that these two aspects are not taken serious enough in the planning and design phase.
Strategic Daily Spot Market Bidding

1. Split your pool into portions and become price maker
2. Optimize your trading volume with intra-day balancing
3. Base your bids on a preliminary plan for the balance process
4. Make sure you help to avoid negative prices

Why is this important?

1. Reduces the day-ahead schedule error with approx. 50%
2. Reduces the need of peak reserve
3. Reduces the volatility of balancing costs
4. More volume in the market
5. Small pools may not need to be 24x7 in the market
How to become a price maker in the market

Recipe:

Know your pool’s controllable and non-controllable generation

Use appropriate uncertainty forecast intervals to:

- trade the “safe” part with a mean or deterministic day-ahead forecast
- trade uncertain parts with higher prices and control curtailment yourself
- trade in the intra-day market only difference outside uncertainty band

Design price levels considering

- time of the day
- current weather situation
- liquidity in the market
- expected load
- risk for negative prices
- risk for curtailment
How to become a price maker in the market

Know, which methodology works for your target problem!

For trading purposes you need an **hour-to-hour uncertainty**, approach:

- (A) generating only a spacial probability distribution lacks the time dimension
- (D) target horizons need calibration for the time component
Thumb rules for trading with uncertainties

Use the **appropriate approach** for your target:
- one that is looking forward in time
- not a statistical/climatology based forecast
- not one that has specific target times

The **incentive** MUST be **avoidance of imbalance costs** while increasing your income

Become a price maker to **reflect real system costs**

Only **trade when it make sense**
- avoid trading every hour/time interval
- only trade within the uncertainty band
- the most current forecast is not always the best !!!
**Ramp Forecast**
A Ramp forecast is a forecast that provides the possible power generation over a specific time interval.

**Risk index of critical Ramps**
A risk index of critical ramps is a threshold value of power generation allowed over a pre-defined time interval. This can be boolean, probabilistic or with sliding ends and tails.
Critical Ramp Events – Definition is key!

Threshold values must be used together with limits and rules, how to act...

Is a 10% probability for a ramp >200MW/15min critical?

..is a 20% probability of a ramp >200mw critical?
Critical Ramp Events – today’s challenge

Statement from a Q&A session at a recent forecasting workshop by an end-user: "Communication of uncertainty in timing of ramp events is the most challenging. It is not so much the uncertainty of the amplitude. **Getting the shape right would already help, even if the timing is off**".

Let’s have a look at that requirement in respect of forecasting method and evaluation:
Beware: if you are interested in the shape - DON’T EVALUATE ON RMSE OR MAE

Phase errors are punished more than shape errors – forecasters listen, but if your choice is measured in MAE/RMSE they can’t do what you ask for and be selected at the same time !!!
Requirement to establish ramp forecasting:

1) **Rules** (when and how to act...)  
2) **Thresholds** (of critical probabilities and timing)  
3) **Limits** (of critical MW ramp up/down per time interval)  
4) **A communication layer** (to interact in real-time with the staff )

Without that, a forecaster cannot provide the necessary information to make such a risk index automatic and reliable!
High-Speed Shutdown Event Forecasting

A warning system can be established in the form of graphics or text.

The underlying instruments however should contain two components:

(1) **Probability computation of the expected cut-off capacity**
In cooperation with the end-user the system critical part of the capacity will be determined (e.g. 30% of the ...)

(2) **Accumulation of the expected cut-off capacity**
This component provides the accumulated cut-off probability of the expected temporal shortage of capacity and ramps
The frequency of alert generation need to be adjusted to:

- lead time of the alert
- initial and valid week day and time of day
- severity of the event computed from a ramp-rate
- change of severity level since previous alert
- the actions required
- the need and possibility to call back and/or revert actions

Strategy of alert issuing:

- issue every alert according to a simple scheme (e.g. probability exceeding 10% for more than 2 subsequent forecasts)
- reduce the amount of alerts to prevent critical alerts not to be overlooked (observe before an alarm is issued...)
Grid Technical Constraints Management

Goals

A. Anticipate technical problems (voltage problems, congestion, etc.)
B. Define remedial actions (e.g. grid reconfiguration, re-dispatch)

Current Practices

- Use of deterministic forecasts, e.g. Day Ahead Congestion Forecast (DACF) - TSO
- DSO do not use forecasts in their management processes OR feed power flow tools with deterministic forecasts for loads/RES
Grid Technical Constraints Management

**Barriers**

Requires stochastic optimization tools with high computational time (slow advices to human operators)

Lack of business cases that perform cost-benefit analysis of stochastic approaches for grid management

Cognitive load of human operators in the presence of probabilistic information for a large electrical network
Grid Technical Constraints Management

Solutions

Integrate forecast uncertainty in “imitation learning” (imitate decisions made by experts)

Ease the acceptance of the information about uncertainty by the human operator

Design local (or segmented) stochastic optimization methods

Decrease the computational time, as well as complexity in visualizing forecasted information

Invest in new visualization techniques

Reduce information into a manageable amount of data and alarms
Key Takeaways...

**Define your problem and request appropriate method**
- Ignoring uncertainty or using wrong tools leads to mistrust
- Applying the right uncertainty tools provides confidence

**Communicating uncertainty can be done in different ways:**
- Use visual as well as textual tools

**Develop or request new visualisation tool**
- Remove concerns by understanding how information can be best condensed to be useful
THANK YOU FOR YOUR ATTENTION

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Publications:
Explanatory additional slides
How to practically work with uncertainty in Trading Applications

- **Case 1**: Short-term forecast
- **Case 2**: Uncertainty band of the forecast
- **Case 3**: Forecast inside uncertainty band - no intraday trading!
- **Case 4**: Trading volume

Day-ahead forecast

Power

Trading volume
How to practically work with uncertainty in Trading Application

There are 4 cases to consider:

Case 1: Short-term forecast is higher than Day-ahead
   Action: **Sell the volume between minimum short-term and day-ahead**

Case 2: Short-ahead forecast is higher than day-ahead, BUT lies within the uncertainty band of short-term forecast
   Action: **Do nothing!**

Case 3: Short-ahead forecast is lower than day-ahead, BUT lies within the uncertainty band of short-term forecast
   Action: **Do nothing!**

Case 4: Short-ahead forecast is lower than day-ahead, BUT lies within the uncertainty band of short-term forecast
   Action: **Buy the volume between maximum short-term and day-ahead**
**Thumb rule 1:** decide objectively which forecast to trust

Forecasts change over time – the latest forecast is not always the best

Example: large difference and uncertainty between previous and latest forecasts, or between different providers

**Solution:**
Use physical uncertainty to make deterministic decisions
decide objectively which forecast to trust/give high weight!
Thumb rule 2: a smooth forecast avoids double punishment and provides “opportunities”

Forecasts never really resemble the variability of measurements:

→ makes it important to avoid double punishment!
How to become a price maker in the market

What are the incentives to bid in with higher prices:

- increase income
- generate realistic prices that mirror the real costs
  Renewables have a free resource, but also need maintenance!
- avoid negative prices in high-penetration situations
- in case of expected shortage to level out higher intra-day prices
- in case of expected surplus to be able to sell lower at intra-day
How to become a price maker: an example

19h

MEAN

20h

MIN

MAX

21h

22h
How to become a price maker in the market

Example of how to generate a price bid

Problem: risk for shortage or negative prices!
- My pool: 200 MW controllable power
- Uncertainty (MAX-MIN): 450 MW
- LS-optimised FC: 1200 MW

=> strategy: bid safe and add some small risk volume for profit and balance

Example at hour 1:
- Bid unlimited: 1200 MW
- Bid price 1 (=0): 80 MW
- Bid price 2 (>+0): 60 MW
- Bid price 3 (>>0): 40 MW
- Bid price 4 (>>>0): 20 MW
How to become a price maker in the market

Example at hour 1:
Bid unlimited 1200MW → market price
Bid price 1 (=0) 80MW → has to prevent negative prices
Bid price 2 (>0) 60MW → has helped increase the market price
Bid price 3 (>>0) 40MW → ...
Bid price 4 (>>>0) 20MW → did not get a contract || need to balance in intraday
How to become a price maker in the market

Low uncertainty:
Least-square optimized or MEAN forecast good!

Real production

High uncertainty:
- reduce imbalance costs
- increase income
- avoid negative prices

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Thumb rules for Trading in DK-NO-SE and DE-AT

North of Denmark: too much wind → **risk of negative prices**

South Sweden: no production → **high imbalance (cost)**

Baltics: congestion from high northsea offshore production → system imbalance high (reserve costs) & **risk of curtailment**

Meteorologically insignificant small differences in path of low pressure system impact market price!

Key factors to consider in any strategy:
- system imbalance
- negative prices
- curtailment