Modelling wind power in unit commitment models

Grid integration session IEA Wind Task 25 Methodologies to estimate wind power impacts to power systems

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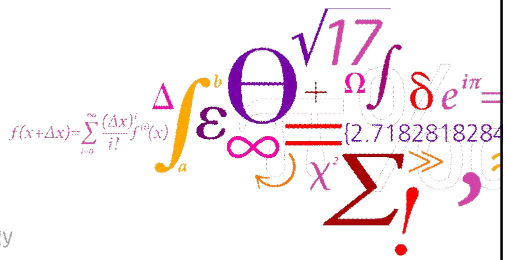

Risø DTU
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OUTLINE

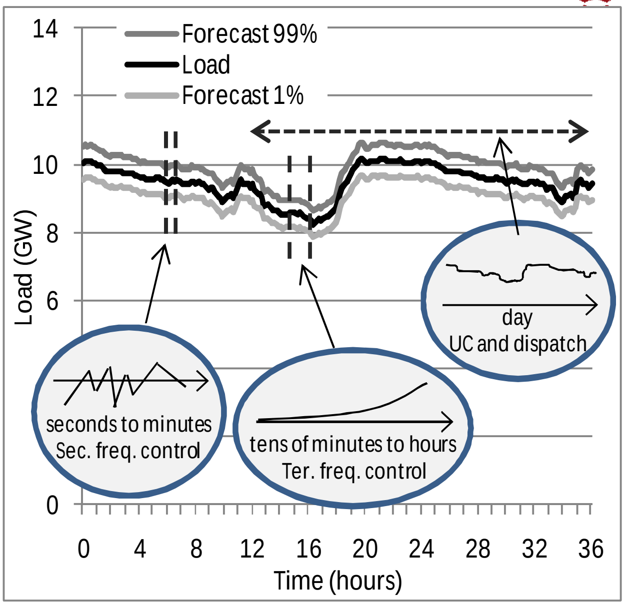
- Unit commitment (UC) without wind
- Variability and wind power forecasts
- Securing enough available capacity
- Changes in UC models
- Illustrative results

UNIT COMMITMENT (UC)

- Selection of online power plants
- Enough online capacity to operate system with high level of security
- Least cost
- In a market based system takes place through spot market bids
- Important due to long start-up times, high start-up costs and restrictions on plant cycling

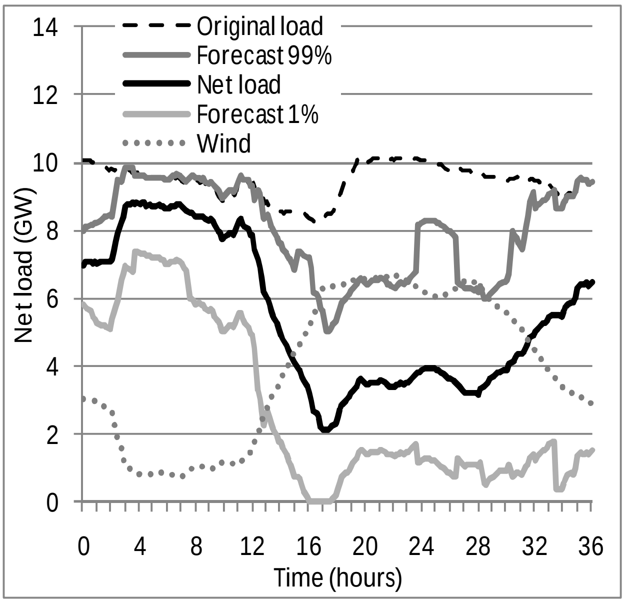
UC & SYSTEM OPERATION WITHOUT WIND

- UC plans the operation for the next day
- Reserves handle load forecast errors and plant outages



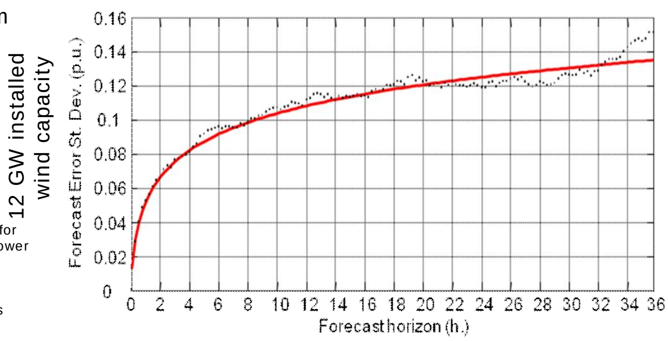
UC & SYSTEM OPERATION WITH WIND

- Expected residual load (load minus wind power production)
- Variability and uncertainty increases
- More flexibility required
  - Generation
  - Responsive load
  - Possible curtailment of wind power



WIND POWER FORECASTS

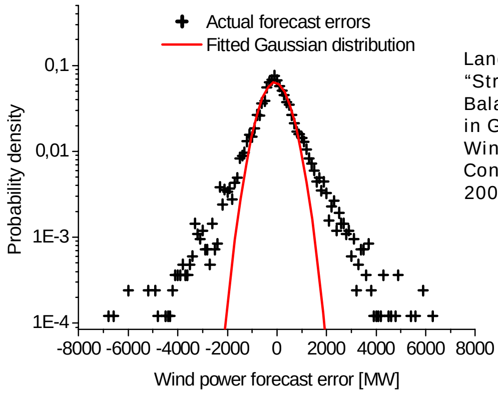
- Wind power forecasts are the ‚schedules' of wind power plants
- But: errors are unavoidable and depend on:
  - Forecast horizon
  - NWP model(s) and online measurements (power, wind) available
  - Installed capacity and size of area
  - Forecast system



Gibescu et al 2009, "Case Study for the Integration of 12 GW Wind Power in the Dutch Power System by 2020." CIGRE/IEEE PES Joint Symposium on the Integration of Wide-Scale Renewable Resources into the Power Delivery System, Calgary, Canada.

WIND INDUCED NEED FOR AVAILABLE CAPACITY

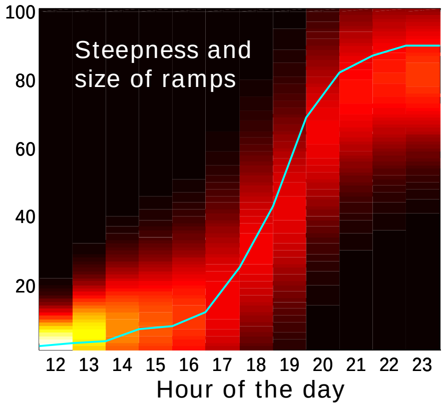
- Possibility of large forecast errors has to be considered
- Wind forecast errors are not normally distributed, large errors occur much more frequently
- This needs to be considered in unit commitment models

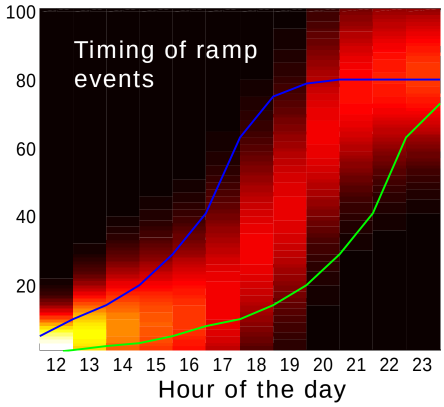


Lange et al (2006), "Strategies for Balancing Wind Power in Germany", German Wind Energy Conference DEWEK 2006.

WIND POWER FORECASTS

- How often new forecasts should/could be available?
- How to present the uncertainty in the forecasts in UC models?





WAYS TO HANDLE THE INCREASED VARIABILITY AND UNCERTAINTY FROM THE UC PERSPECTIVE

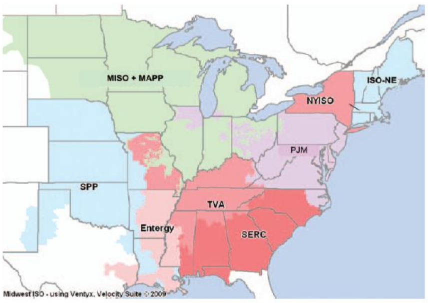
- Incorporate several wind power forecasts in:
  - UC process (e.g. pre-processing stochastic information, stochastic scenarios)
  - Dynamic reserve requirements
- Use updated wind power forecasts:
  - Intra-day rescheduling of UC realised by liquid intra-day markets
- Allow for curtailment of wind power when it is the most cost effective solution

<table>
<tr><td>Perfect forecast</td><td colspan="3">Perfect information about wind power production and electricity demand in the day-ahead timescale. Can be used as a base case for estimating the cost of uncertainty.</td></tr>
<tr><td rowspan="2">Single forecast with a static reserve</td><td rowspan="2">A rule based adder for reserves is used to account for uncertainty.</td><td colspan="2">UC only in day-ahead
With significant wind power penetration a large tertiary reserve would be required.</td></tr>
<tr><td colspan="2">Intra-day UC
Decreases the required reserve adder and the amount of wind curtailment.</td></tr>
<tr><td rowspan="3">Single forecast with a dynamic reserve</td><td rowspan="3">The UC model is deterministic with one forecast, but the data about wind and demand uncertainty has been pre-processed to create a reserve requirement that is based on probabilistics.</td><td colspan="2">UC only in day-ahead
With significant wind power penetration a large tertiary reserve would be required.</td></tr>
<tr><td rowspan="2">Intra-day UC</td><td>Statistical rules
Pre-processing is based on statistically derived rules.</td></tr>
<tr><td>(LOLP) approaches
Convolution of various probabilities to arrive at the desired LOLP.</td></tr>
<tr><td>Stochastic scenarios</td><td colspan="3">Optimization of UC decisions over several scenarios for possible outcomes of wind and demand. Scenarios cover part or all of the tertiary reserve requirement.</td></tr>
</table>

Advanced Unit Commitment in the Eastern Interconnect

- Project Team
  - NREL – Project Management, data and modeling for the US
  - Risoe DTU – developer of the Scheduling Model
  - Univ Stuttgart IER – developer of the Scenario Tree Tool
  - ECAR – Assistance on analysis and model runs
- Objectives
  - Understand the impacts of forecast error on the eastern interconnect
  - Understand the impacts and benefits of stochastic planning on the eastern interconnection
  - Understand the impacts and benefits of rolling UC updates on the eastern Interconnection
- Scope
  - Uses the WILMAR tool
  - Uses consistent data with Eastern Wind Integration and Transmission Study
  - Three data years, 4 unit commitment scenarios, sensitivity requiring coal as must run

Study System



EWITS Scenario 2:
"Hybrid with Offshore"

Region	Onshore (MW)	Offshore (MW)	Total (MW)	Annual Energy (TWh)
ISO-NE	8,837	5,000	13,837	46
MISO+MAPP	69,444	0	69,444	288
NYISO	13,887	2,620	16,507	48
PJM	28,192	5,000	33,192	97
SERC	1,009	4,000	5,009	16
SPP	86,666	0	86,666	245
TVA	1,247	0	1,247	4
Total	209,282	16,620	225,902	745

The WILMAR tool

- Improve decision making by using information contained in wind power production and load forecasts
- Information: Expected wind power production and load, but also precision of forecast, i.e. the distribution of the wind power production forecast errors
- Information accuracy improves as you get closer to real-time

- Stochastic Planning: Planning with representation of stochastic variables to provide for a more robust system
- Rolling Planning: Using updated information to adjust unit commitment decisions more frequently.

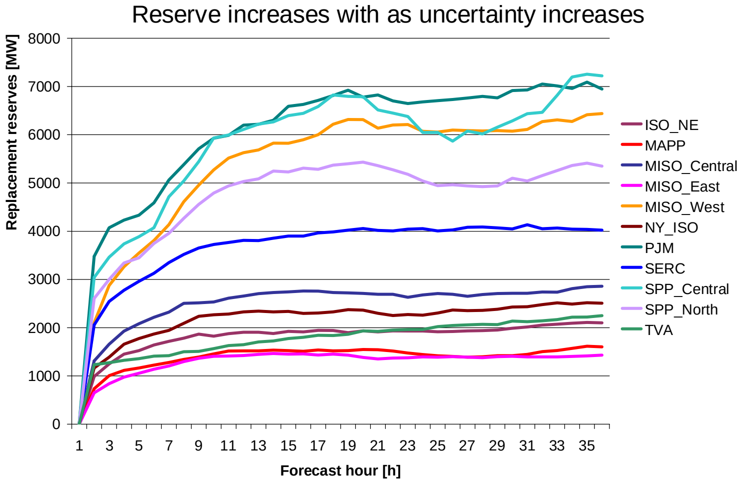
The WILMAR tool

- How:
  - Build system-wide stochastic optimisation model with the wind power production and load as a stochastic input parameter
  - Covering both day-ahead scheduling and rescheduling due to updated wind power and load forecasts
- Consequence: Model makes unit commitment and dispatch decisions being robust towards wind power production and load forecast errors

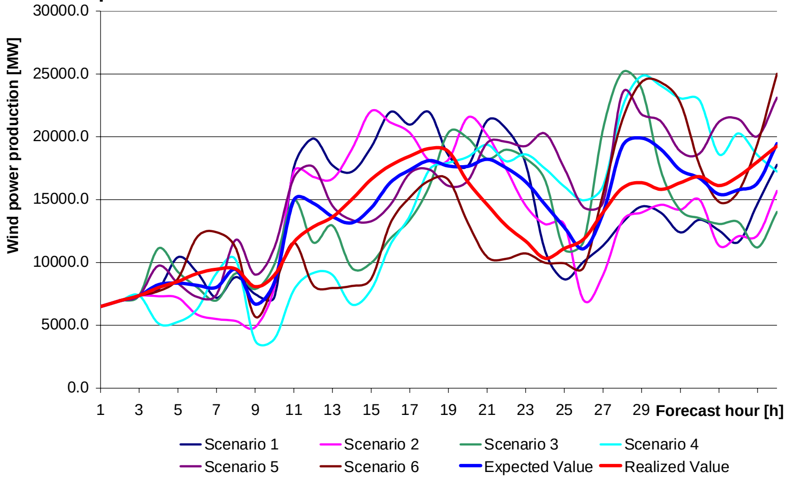
Scenario Tree Tool

- Generation of scenario trees containing stochastic input parameter for Scheduling Model:
  - Wind power forecasts
  - Load forecasts
  - Demand for replacement reserves
- Generation of Semi-Markov processes describing availability / unavailability of power plants
- Implemented in Matlab
- Replacement reserve (positive reserves for different forecast horizons):
  - Demand time and scenario dependant (determined for forecast horizons from 1 hour to 36 hours ahead)
  - Demand dependant on wind power and load forecasts
  - Offline units can provide this type of reserve if they have start-up times of less than an hour

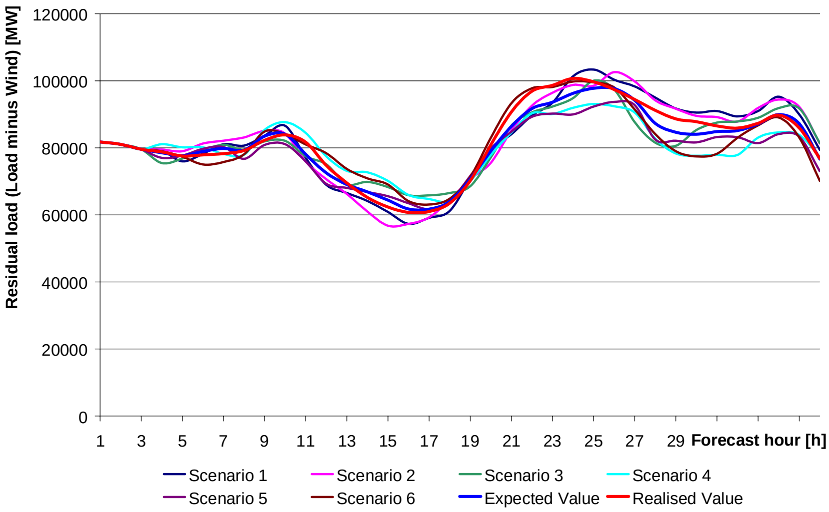
Replacement Reserves



Example Wind Forecasts



Example day-ahead scenario tree for PJM net load



Scheduling model

- First three hours in scenario tree deterministic:
  - Realized wind power production
  - Realized load
  - Demand replacement reserve (taking uncertainty in wind power production forecasts and load forecasts for forecast horizons 1 to 3 hours ahead into account)
- Optimization over all outcomes represented by the scenario tree taking both demands for electricity and demand for spinning and replacement reserves into account
- Minimization of expected costs. Expectation taken over branches in scenario tree
- Unit restrictions: minimum up time, minimum down time, start-up time, minimum stable operation level, piece-wise linear fuel consumption curve, restriction on ability to provide spinning reserve, ramp up rates, ramp down rates, etc.
- Implemented in GAMS using CPLEX solver

Representation of transmission grid

- Model area divided into EWITS regions
- Regions connected by transmission lines
- No grid representation within a region (only average transmission and distribution loss)
- Energy exchange between regions. Grid restrictions expressed by usage of NTCs (net transfer capacities)
- Monthly NTCs obtained from Promod load flow calculations

Results

- Model runs:
  - STO: Stochastic planning using scenario trees with six branches (six forecasts), unit commitment updated every 3 hours
  - UCDay: Stochastic planning, unit commitment for units with start times greater than 1 hour, updated once per day in the day-ahead market
  - OTS: Deterministic planning with forecast error (only one forecast), unit commitment updated every three hours
  - PFC: Deterministic planning with perfect foresight i.e. wind power and load forecasts corresponds to realized wind power and load.
- Comparisons of these model runs gives insight into the differences of forecast error, stochastic planning, and rolling UC updates

Operational costs (mainly fuel costs)

- Value intra-day rescheduling: 778 M$ (1.3%) (UCDay minus STO)
- Value stochastic UC: 207 M$ (0.36%) (OTS minus STO)
- Value perfect foresight: 426 M$ (0.7%) (STO minus PFC)
- It appears rolling unit commitment gives more value than stochastic planning