Estimating contracted regulating power in the Danish electricity system

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Content

- Structure of Nordic power market
- Terminology
- Why option payment for reserves?
- Methodology for estimating demand for contracted regulating power
- Case study
- Results
- Conclusions

Structure of Nordic power market

Operation hour	Hours before	Day before	Weeks to years
Regulating power market (real-time market): - Activation tertiary reserves Automatic regulation (primary/secondary reserves)	Intra-day market (Elbas): - Rescheduling production and power exchange	Estimate need for tertiary reserves Procurement tertiary reserves Day-ahead power market (Elspot): -Hourly contracts for physical power delivery - Hourly power exchange	Financial markets: - Hedging, speculation - Forward, futures, options Fuel contracts Procurement of ancillary services

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Terminology

- Tertiary reserves:
  - positive and negative reserves with activation times of approximately 15 minutes
- Regulating power market:
  - flexible producers and consumers place tertiary reserve bids up to 45 minutes before operation hour
  - in case of deviations between production and consumption plans and realised production and consumption: activation of tertiary reserves during actual operation hour
  - operated by Nordic TSOs
- Regulating power:
  - tertiary reserves bid into the regulating power market

Terminology

- Market based regulating power:
  - tertiary reserves bid into the regulating power market without receiving an option payment
  - Receives regulating power market price when activated
- Contracted regulating power (manuel reserves):
  - positive tertiary reserves paid an option price on daily auction for reserving production capacity for the regulating power market
  - Receives regulating power market price when activated

Why option payment for contracted regulating power?

- Security of supply:
  - ensure sufficient amounts of positive regulating power available in each operation hour
  - responsibility of TSO (buyer of regulating power)
  - high social costs of lost load
- Power producers (offering regulating power):
  - Profit maximisation
  - difficult to optimise towards both day-ahead and regulating power market
  - uncertain income on regulating power market
  - low revenue on regulating power market compared to day-ahead
- Tradition/history
- Can not be understood from a perfect market perspective!

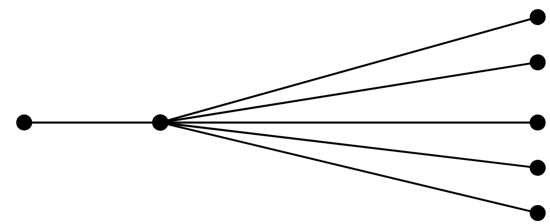
Methodology

- Using Wilmar Planning tool for unit commitment UC) and economic dispatch
- UC slow plants (start-up time ≥ 1 hour) determined day-ahead
- Extreme forecasts included in scenario tree:
  - large set of forecast scenarios generated by Monte Carlo sampling
  - Set reduced by clustering
  - extreme forecasts equal to upper tail percentile from the distribution of each cluster

Methodology

1. Model run only taking day-ahead market into account. UC based on expected wind power and load forecasts

2. Model run also taking regulating power market into account. UC based on several wind power and load forecasts



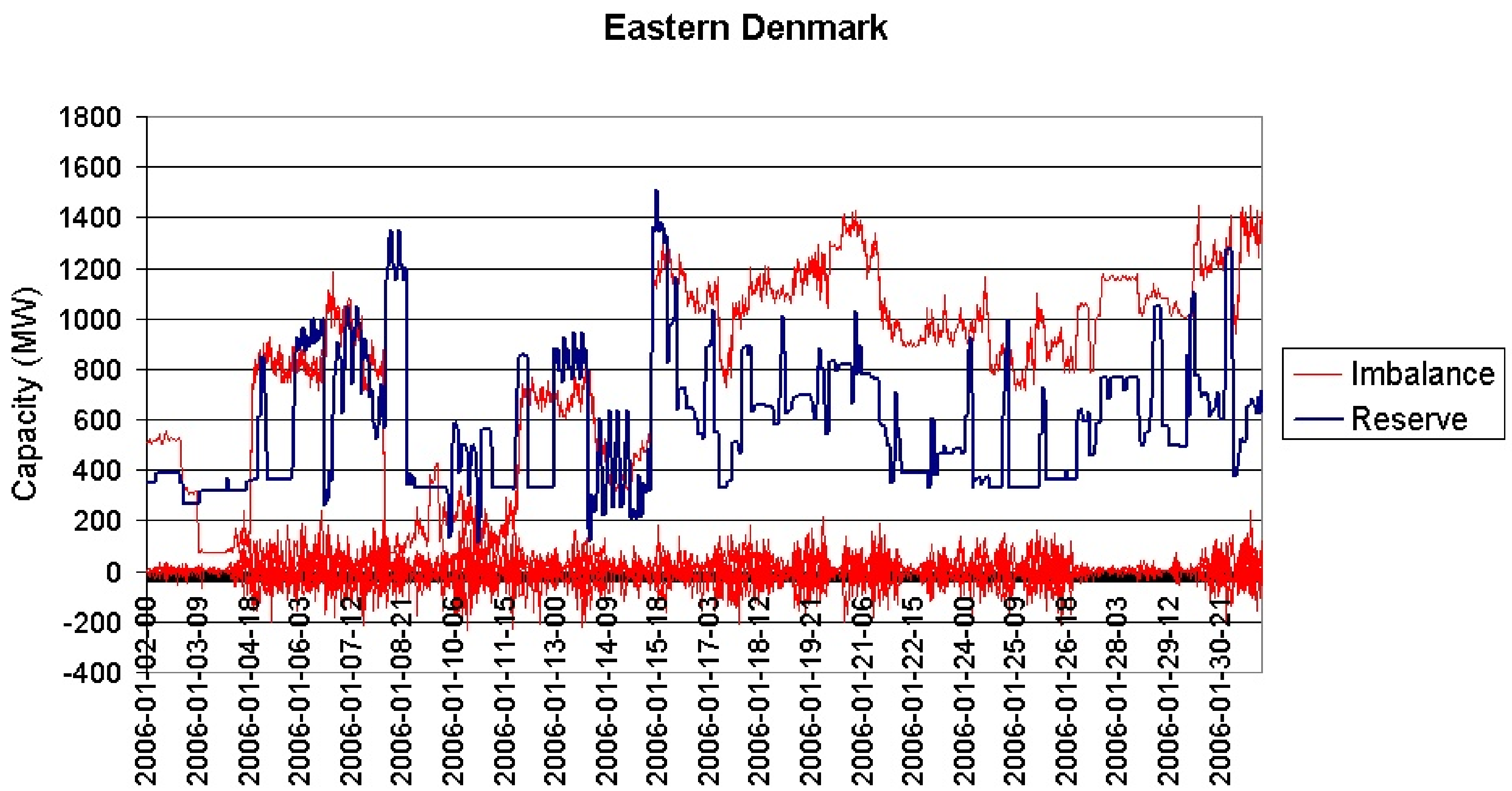
3. Capacity online in 2 minus capacity online in 1 equal to contracted regulating power demand

4. Idle online capacity in 1 also offered as contract regulating power

Case study

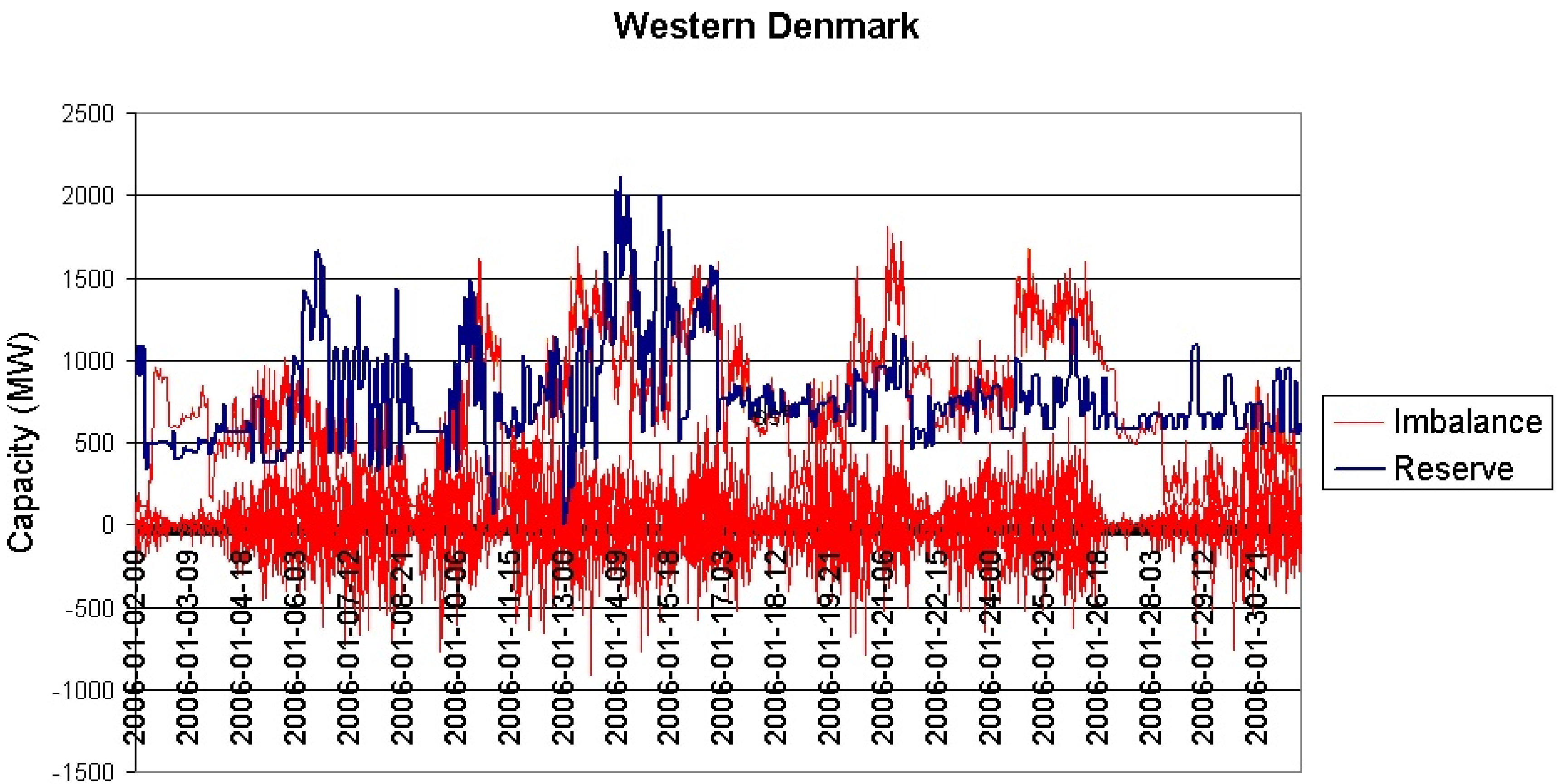
- Denmark, Finland, Germany, Norway, Sweden
- Denmark split into two regions
- UC of production units in Denmark treated with integers
- UC of other production calculated by relaxing integer restriction
  - (0≤ online status ≤ 1)
- January 2006

Results



Hourly amounts of contracted regulating power capacity and system imbalances for Eastern Denmark, January 2006

Results



Hourly amounts of contracted regulating power capacity and system imbalances for Western Denmark, January 2006

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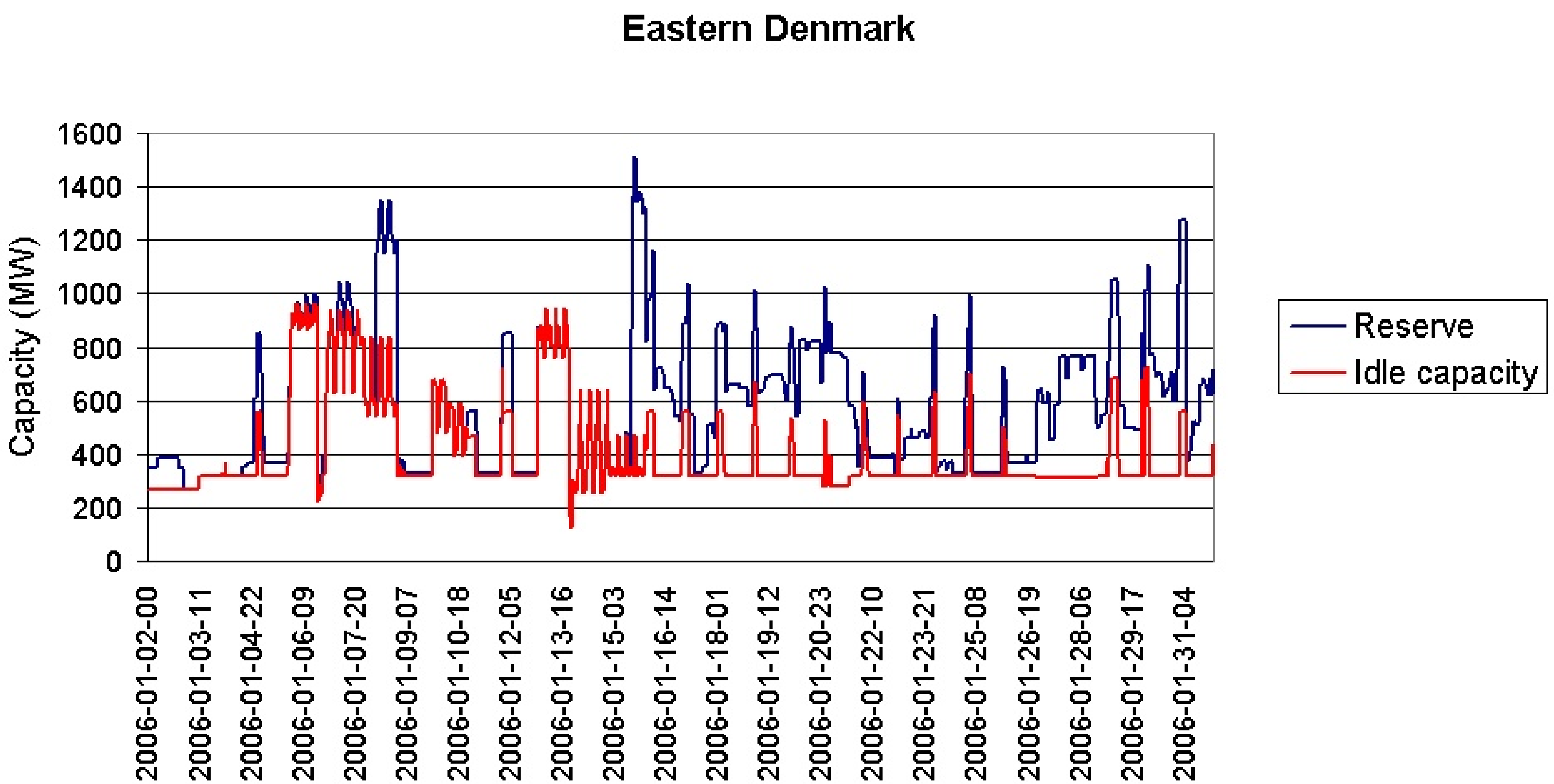

Hourly amounts of contracted regulating power capacity and idle capacity for Eastern Denmark, January 2006

Conclusions

- Methodology established for estimating demand for contracted regulating power
- Contracted regulating power demand varies a lot from hour to hour dependant on day-ahead forecast error distribution
- Option payment will be paid to production units having idle capacity as a result of day-ahead market solution