Modelling an Integrated Northern European Regulating Power Market Based on a Common Day-Ahead Market

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Outline

• Introduction

• Integrated regulating power market model
  – Day-ahead market
  – Regulating reserve procurement
  – System balancing

• Case studies

• Conclusion
“Balance Management in Multinational Power Markets”

- Sustainable (intermittent) electricity production => need for regulating resources
- Cross boarder trade => integration of national regulating energy markets
- Aim to integrate northern European regulating power markets
Modelling objective

- Increasing intermittent power generation => utilization balancing capabilities of Nordic hydro-based power system
- Investigation of:
  - Possibility of foreign regulating reserve procurement
  - System wide regulating resource exchange (real-time system balancing)
  - Transmission reservation for reserve procurement and system balancing
  - Regulating reserve and resource pricing
- Estimation of socio-economic benefit of integrating multinational regulating power markets
- Analysis of different regulating power market integration steps
Overview

- Integrated regulating power market based on a common day-ahead market
- Covers Denmark, Finland, Norway, Sweden, Germany, Netherlands (Northern Europe)
- Fundamental model
- Perfect market assumption
- Hydro system inflow / wind production scenarios: 1951-1990
Structure

Input:
- Power plant data
- Transmission system data
- Demand, Ex-&Import curves
- Hydro inflow, wind speeds

Model:
- Day-ahead market
  - Generation dispatch
  - Water values
  - Area prices
- Reserve procurement
  - Generation redispatch
  - Water values
  - Area prices
- System balancing

Output:
- Total production cost
- Area prices
- Optimal generation dispatch
- Transmission dispatch
- Reserve procurement cost
- Availability of regulating reserves
- System balancing cost
- Regulating resource exchange

EMPS – EFI’s Multi-area Power-market Simulator
IRiE – Integrated Regulating power market in Europe
Day-ahead market

**Input:**
- Power plant data
- Transmission system data
- Demand, Ex-&Import curves
- Hydro inflow, wind speeds

**Model:**
Day-ahead market
- Generation dispatch
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Reserve procurement
- Generation redispatch
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System balancing
- System balancing cost
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**Output:**
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EMPS
- Water values
- Area prices
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IRiE
- System imbalance:
  - Demand forecast error
  - Wind forecast error

EMPS IRiE
EMPS – Common day-ahead market

- Mid- and long-term optimisation of system operation on weekly basis (containing several periods)
- Developed at SINTEF Energy Research
- Key points:
  - Transmission system (NTCs, linear losses)
  - Nordic hydro system (reservoirs, power plants and water course)
  - Thermal scheduled production & dispatchable production (power plants with marginal production- & start up costs)
  - Wind power generation
  - Consumption (temperature dependent)
- Results:
  - Optimal unit commitment and generation dispatch
  - Area prices, water values
Reserve procurement

Input:
- Power plant data
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Model:
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IRiE

NTNU
Norwegian University of Science and Technology
IRiE - Reserve procurement

**Objective:** least cost redispatch of generation and transmission capacity in order to fulfil given reserve requirements

- Procurement of up- & downward regulating reserves
- Reserve procurement cost includes:
  - Production decrease on infra marginal units / Production increase on ultra marginal units
  - Efficiency loss for thermal units at partial load
  - Start up- / shut down costs of thermal units
Reserve procurement strategy

Before procurement:

Upward regulating reserves:

Downward regulating reserves:

After procurement:
Reserve requirements

- Requirements for secondary reserves (UCTE) and Frequency restoration reserves (Nordel)
- Aggregation of control areas into balancing areas (Nordel, DE, NL)

<table>
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<th>Control Area</th>
<th>Balancing Area</th>
<th>Total system</th>
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</table>
System balancing

Input:
- Power plant data
- Transmission system data
- Demand, Ex- & Import curves
- Hydro inflow, wind speeds

Model:
- Generation dispatch
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- Area prices

Output:
- Total production cost
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- Transmission dispatch

EMPS
- Reserve procurement
- Reserve procurement cost
- Availability of regulating reserves

IRiE
- System balancing cost
- Regulating resource exchange

System imbalance:
- Demand forecast error
- Wind forecast error

Reserve requirements:
- Control area
- Balancing area
- System wide

Day-ahead market
- Water values
- Area prices
- Power plant data
- Transmission system data
- Demand, Ex- & Import curves
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Reserve procurement
- Water values
- Area prices
- Generation redispatch
- Reserve procurement cost
- Availability of regulating reserves

System balancing
- System balancing cost
- Regulating resource exchange
- Water values
- Area prices
IRiE - System balancing

**Objective**: least cost system wide generation and transmission redispatch to settle real-time system imbalances in each PTU

- Input: imbalance records (quarter hourly)
- No time dependencies (ramping, start up / shut down of units)
- Definition of non-spinning in addition to spinning regulating reserves
  => all installed generation capacity available for system balancing
Case studies
Integration of regulating power markets

• Studied years:
  – Wet year – hydro inflow = 244 TWh
  – Dry year – hydro inflow = 146 TWh

• Exchange of regulating resources: Case:
  – No exchange between control areas in Germany (I)
  – Exchange only in balancing areas (II)
  – System wide exchange (III – V)

• Regulating reserve procurement:
  – Procurement only in own control area (I – III)
  – Procurement in whole balancing area (IV)
  – Reserve procurement system wide (V)
Regulating reserve procurement

- Significant reduction of necessary redispatch for reserve procurement approx. 30%

- Procurement costs:
  - wet dry
  - 3: 91,92 436,1 M€
  - 4: 70,71 110,8 M€
  - 5: 49,81 88,12 M€
Reserve activation

- Reduction rationing / shutdown to nearly zero with exchange of regulating resources

- Imbalance settlement costs:
  - wet: 180 207 M€
  - dry: 96 113 M€
  - 3: 60 73 M€
Conclusion

• Decrease redispatch during reserve procurement by 30% => ample regulating reserves available in Nordic system
• Reduction reserve activation by 30% (imbalance netting)
• Gross exchange of balancing energy approx. 2 TWh – 40% of activated regulating reserves
• Significant reduction of reserve procurement and reserve activation costs
• Further work
  – Model with better grid representation
  – Improvement in description of reserve costs
  – Modelling of future scenarios – 2020/2030