Impact of imbalance costs on stochastic unit investments

Salvador Pineda (and Juan Miguel Morales)

Workshop on Modelling Investment in Power Systems (27/03/2014)

Work supported by 5s project (http://www.futureelmarket.dk/)
Assumptions

• Static investment model (one target year)
• Long-term uncertainties disregarded
• Energy-only markets (no capacity or CO2 payments)
• No support scheme for renewables
• No competition at investment level
• Perfect competitive market (offers = marginal cost)
Expansion of stochastic units

Bus 1

Bus 2

Low wind

High wind

Location of wind turbines?
Imbalance costs of wind

“The three study cases show that the error prediction costs can reach as much as 10% of the total WP incomes from selling energy.” [1]

“The predictions were analysed together with the electricity market prices for Denmark, using actual data from year 2001 (...) Costs from the regulation market for the prediction errors for 12–36 h ahead market were 2.3 Eur/MWh total wind power production, resulting in net income of 20.1 Eur/Mwh” [2]

“Over 2002, the average spot price of APX is 29.99 euros/Mwh (...) Even if using perfect predictions, the average price per produced Mwh by a wind power producer equals 28.37 euros/Mwh (...) When considering regulation costs, the average price per produced MWh lowers to 24.68” [3]
Expansion of stochastic units

Location of wind turbines?

Bus 1
Low wind
Cheap balancing

Bus 2
High wind
Expensive balancing
Expansion of thermal units

Power producer
Decide new units
Maximize profit

Day-ahead market
Decide dispatch
Minimize cost

Capacities & location
Dispatch & prices
Expansion of thermal units

Power producer
- Decide new units
- Maximize profit

Day-ahead market
- Decide dispatch
- Minimize cost

Dispatch & prices

Bilevel model
- Maximize profit
- Investment constraints
- Solve replacing lower-level problem by its KKT conditions

Day-ahead market
- Decide dispatch
- Minimize cost
Expansion of stochastic units

- Power producer
  - Decide new units
  - Maximize profit
- Capacities & location
- Day-ahead market
  - Decide dispatch
  - Minimize cost
- Dispatch & prices
Market design

• Day-ahead vs. balancing markets

**Day-ahead market**
- Power producers submit offers for the next 24 hours
- The demand and stochastic production are forecast
- The cheapest offers are accepted first

**Balancing market**
- Power producers submit offers to deviate from schedule
- The demand and wind realize at this stage
- The cheapest offers are accepted until deviations are balanced out
Market design

• Coordination between day-ahead and balancing

**Conventional MC**
Day-ahead dispatch compute disregarding balancing operation

**Stochastic MC**
Day-ahead dispatch takes into account balancing operation
Market design

Forecast = 100 MW
Wind (30%) = 130 MW

Conv MC

Stoc MC
Market design

Conv MC

- Day-ahead dispatch: cheaper go first
- Balancing operation not included
- Minimizes day-ahead cost
- All units obtain profits

Stoc MC

- DA dispatch: out of merit-order
- Balancing operation included
- Minimizes total cost
- Reduces imbalance cost
- Flexible units may incur losses
Expansion of stochastic units

**Investment under Conv MC**
- Power producer
  - Decide new units
  - Maximize profit
- Market operator
  - Capacities & location
  - Dispatch & prices
  - Day-ahead
  - Balancing

**Investment under Stoc MC**
- Power producer
  - Decide new units
  - Maximize profit
- Market operator
  - Capacities & location
  - Dispatch & prices
  - Day-ahead
  - Balancing
Expansion of stochastic units

Bilevel model
Maximize profit
Investment constraints

Investment under Conv MC

Market operator

Day-ahead
Balancing

Investment under Stoc MC

Bilevel model
Maximize profit
Investment constraints

Market operator

Day-ahead
Balancing
Illustrative example

Low wind
Cheap balancing
Bus 1

High wind
Expensive balancing
Bus 2

Conv MC

Wind investment capacity (MW)

Stoc MC

Wind investment capacity (MW)
Illustrative example

Low wind
Cheap balancing

Bus 1

Bus 2

High wind
Expensive balancing

Conv MC

Stoc MC

Demand covered by wind (%)
Conclusions

Investment model
Maximize profit
Day-ahead

Investment (Conv MC)
Maximize profit
Day-ahead
Balancing

Investment (Stoc MC)
Maximize profit
Day-ahead
Balancing

≠

<
Thanks! Questions??

Submitted to *Operations Research*
manuscript (Please, provide the manuscript number!)

Modeling the Impact of Imbalance Costs on Generating Expansion of Stochastic Units

Salvador Pineda  
University of Copenhagen, s.pineda@math.ku.dk

Juan M. Morales  
Technical University of Denmark, jmmgo@imm.dtu.dk

---

Impact of Forecast Errors on Expansion Planning of Power Systems with a Renewables Target