Coordinated bidding in the Nordic day-ahead and balancing market

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Sell the same product in multiple markets

Figure taken from NVE
https://www.nve.no/energy-market-and-regulation/wholesale-market/wholesale-market-timeframes/
Easy! Just sell at the highest price!

Day-ahead market
Price = 30

Sell as much as possible
Easy! Just sell at the highest price!

Day-ahead market  
Price = 30  
Sell as much as possible

Intraday market  
Price = 45  
Sell even more!
Easy! Just sell at the highest price!

Day-ahead market
Price = 30
Sell as much as possible

Intraday market
Price = 45
Sell even more!

Balancing market
Price = 60
Sell everything!
Allocation problem

Day-ahead market
Price = 30
Sell as much as possible!

Intraday market
Price = 45
Sell even more!

Balancing market
Price = 60
Sell everything!

\[
\max \sum_{\text{all markets}} \text{sale volume} \times \text{price}
\]

Result: trade all available capacity in the market with highest price
But the real world is more complicated
Complicating fact no 1: Future prices are not known

Figures taken from
Michal Kaut
http://work.michalkaut.net/papers_etc/sg_forecast-errors.pdf
NordPool
SINTEF
Complicating fact no 2: The production system is complex
Solution

Implement multiple markets in (the stochastic version of) the production scheduling model used by Nordic hydropower producers

\[
\max \sum_{all\ markets} sale\ volume \times price
\]

Subject to:
Market dynamics and stochastics
The production system

Result: Something that takes a long time to solve
Results from example case
Results from example case
Results from example case