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## the way when **Coordinated bidding in** Nordic day-ahead and balancing markets Gro Klæboe gro.klaeboe@powel.com

Helping utilities work smarter

### Nordic day-ahead and balancing markets

- Majority of energy consumption (~80%) traded in Nord Pool Spot day-ahead market (DAM)
- Trades in DAM basis for settlements
- TSO single buyer in balancing market
- Both DAM and BM are energy-only markets
- By regulation:

Balancing market price<sup>up</sup> > day-ahead market price Balancing market price<sup>down</sup> < day-ahead market price



## Market timeline





#### **Decision stages: Separate vs Coordinated bidding**



1. Day-ahead market bidding

2. Balancing market bidding

3. Dispatch

#### Separate bidding

Day-ahead market price branch
Balancing market price branch



Coordinated bidding



## Are we able to forecast balancing market prices?



#### Benchmarking of balancing market price premiums for price area NO2 balancing prices week 1-12 2013

#### Models for:

- Balancing market states
- Balancing market volumes
- Balancing market price premiums  $\delta = \rho^{BM} \rho^{DAM}$

Energy Syst (2015) 6:43-61 DOI 10.1007/s12667-013-0103-3

#### ORIGINAL PAPER

#### Benchmarking time series based forecasting models for electricity balancing market prices

Gro Klæboe · Anders Lund Eriksrud · Stein-Erik Fleten

Received: 6 September 2013 / Accepted: 18 November 2013 / Published online: 7 December 2013 © Springer-Verlag Berlin Heidelberg 2013

Abstract In the trade-off between bidding in the day-ahead electricity market and the real time balancing market, producers need good forecasts for balancing market prices to make informed decisions. A range of earlier published models for forecasting of balancing market prices, including a few extensions, is benchmarked. The models are benchmarked both for 1 h-ahead and day-ahead forecast, and both point and interval forecasts are compared. None of the benchmarked models produce informative day-ahead point forecasts, suggesting that information available before the closing of the day-ahead market price. Evaluation of the interval forecasts reveals that models without balancing state information overestimate variance, making them unsuitable for scenario generation.



#### **Models for balancing market price premiums**

Name	Balancing state	Balancing volume	Balancing market price	Inspiration
EXO	Arrival rate	AR1 for unevenly spaced ts	Function of price, volume and direction	Jahnert et al 2009
ARM	Markov	None	ARMA	Olsson & Söder 2008
ARX	None	None	AR1 with DaM as exogenous input	Boomsma et al 2014
ARMA	None	None	ARMA(1,1)	Jahnert et al 2009
Naive	None	None	Similar day	Conejo et al 2005

#### **MAE for BM price premium point forecasts**

w	$ \overline{\delta_t} $	1 h ahead forecast				Day ahead forecast					
		ARMA	ARX	ARM	EXO	NAIVE	ARMA	ARX	ARM	EXO	NAIVE
1	40.82	14.89	19.39	11.51	26.50	9.68	40.92	41.11	40.31	40.76	46.61
2	53.19	29.21	49.61	28.76	45.68	29.41	53.37	52.89	54.55	53.31	64.91
3	93.19	48.63	68.32	50.92	82.98	42.56	93.03	94.77	93.39	94.12	145.76
4	64.23	41.05	72.61	43.64	62.56	42.63	64.81	65.12	64.20	65.69	85.62
5	40.86	14.70	18.02	9.78	26.95	9.57	41.06	41.18	39.17	41.13	42.84
6	30.15	15.32	23.80	15.28	22.81	15.19	30.36	30.28	31.21	30.18	38.52
7	36.98	18.03	25.51	17.02	32.70	16.03	37.66	37.44	37.89	37.63	47.43
8	31.38	12.38	16.09	9.98	25.88	9.10	31.75	31.79	30.57	32.39	35.26
9	32.90	11.90	14.73	8.24	19.44	7.52	33.13	32.97	31.91	33.16	21.19
10	32.66	12.44	14.63	10.26	19.53	8.58	32.69	32.62	31.61	32.06	29.08
11	89.66	49.27	82.98	49.16	78.58	52.48	89.74	90.22	88.40	90.28	131.84
12	87.58	63.25	88.48	57.07	81.80	64.68	87.58	88.39	87.98	87.85	145.47

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#### **Evaluation of BM price premium probablisitic** forecasts

Table 11: Unconditional coverage. Percentage of observed balancing market premiums that fall within the interval specified by the simulated values' median +- range/2

	One hour ahead forecast				Day ahead forecast			
range	ARMA	ARX	ARM	EXO	ARMA	ARX	ARM	EXO
50%	86.51	79.01	39.01	58.44	80.36	80.63	37.76	14.27
75%	91.98	89.22	79.84	67.71	92.97	92.76	78.13	77.19
90%	94.48	92.45	88.70	83.07	95.21	95.21	89.32	91.56
99%	96.77	94.69	94.64	96.09	97.08	97.24	95.36	96.41



#### **Balancing market price forecasts - conclusions**

- Point forecasts:
  - No method gives informative day-ahead forecasts
  - Naive forecasts are hard to outperform for hour ahead forecasts
- Probabilistic forecasts:
  - Methods which explicitly model the balancing state gives a better representation of the variance
  - Important to separate the probability of a balancing event from the probability of its magnitude



Coordinated vs separate day-ahead market bidding Is coordinated bidding worth the effort?



#### IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. XX, NO. XX, MARCH 2015

#### Day-Ahead Market Bidding Taking the Balancing Power Market Into Account

Gro Klæboe, Member, IEEE, Jørgen Braathen, Anders Lund Eriksrud, Member, IEEE, and Stein-Erik Fleten,

*Abstract*—This article quantifies the gains of coordinating bids to the day-ahead electricity market (DAM) and balancing market (BM), compared constructing bids for the two markets separately. A technically detailed case-study of a hydropower producer shows no obvious gains under current market conditions. However, coordinated bidding gives bids that increases flexibility.

#### **Stochastic parameters:**

- $\rho_{mts}$  Market price
- $\nu_{mts}$  Volume in balancing market
- $\delta_{ts}$  Balancing market premium
- $\sigma_{ts}$  Risk adjusted cost of imbalance



# How will day-ahead market bidding benefit from modelling the balancing market?

BM price premium compared to DAM	Water value compared to DAM price				
	Low	High			
Low	Bid so that expected production equals 0	Bid so that expected production is according to water value			
High	Bid in order to benefit from down-regulation	Hold back volumes in DAM to benefit from up-regulation			



### **Case study: Coordinated vs separate BM-bidding**



- Four-day case from autumn 2012
- Real data provided by Norwegian hydro power producer



### **Modelling of the balancing market**

- Traded volumes are a result of random events
- Volumes must and will be limited, seen from a system security point of view
- Thus, the producer faces an uncertain balancing direction and balancing state
  - -> Risk of not being dispatched
  - -> Limits (random) to how much that can be sold in BM

The EXO-model was used both for modelling balancing market volumes and balancing market price premiums.



#### **Calculation times experiences**

- Extremely hard problem to solve:
  - Minimum scenario set with 300 scenarios (30 DAM \* 10 BM price scenarios)
  - Solution times 8700 s (~ 3 hours)
    - CPLEX 12.2 on an 8-core 2.6 GHz HP CPU with 64Gb RAM



#### **Case study gains from coordinated bidding and balancing market participation**

	Profit increase compared to one day income
Coordinated vs. Separate bidding	0.1%
Participating vs. Not participating in the balancing market	3.1%



#### ... but DAM bids exhibited new patterns...

Hour 1





- Modelling coordinated bidding is computationally challenging
- Gains from coordinated bidding seems limited
- It has a value to participate in the balancing market
- Bids reflect more positioning for flexibility might increase value with higher price differences in DAM and BM



#### Litterature

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