Price Forecasting And Unit Commitment in Electricity Markets

J. Bouchard

A. Botterud

P. Thimmapuram

Argonne NATIONAL LABORATORY

EDF CHANGER L'ÉNERGIE ENSEMBLE

Agenda

- Model and Methodology
- Survey Framework
- Results
- Conclusions

Model & Methodology

EMCAS

Energy Market Complex Adaptative System

Argonne NATIONAL LABORATORY

EDF CHANGER L'ÉNERGIE ENSEMBLE

An Agent-Based Model

- EMCAS is Argonne's Most Advanced Analysis Tool and is Used to Study Power Markets in Different Stages of Restructuring
- Uses an agent-based modeling approach to represent multiple market participants (agents) with decentralized decision-making under uncertainty
- Each agent has its own characteristics
  - Asymmetric information
  - Risk preferences may vary
  - Agents can learn, adapt, and change their behaviour during the simulation

Detailed physical representation of the power system

- Different generation technologies
  - Thermal, hydro, wind, etc.
- Hourly simulations of supply-demand equilibrium
  - Bid-based scheduling (day-ahead) and dispatch (real-time) based on DC-OPF
  - Planned and forced generator outages
- Calculation of prices based on “two-settlement system”
  - Day-ahead (DA) schedule at DA price
  - Deviations from DA at real-time (RT) price

Price Forecasting
& Unit Commitment

Argonne NATIONAL LABORATORY

eDF
CHANGER L'ÉNERGIE ENSEMBLE

Price Forecasting

- Each player forecasts next day's hourly price based on information shared by all players:
  - Previous day hourly prices
  - Previous day System Reserve Margin (SRM)
  - Next day's hourly load

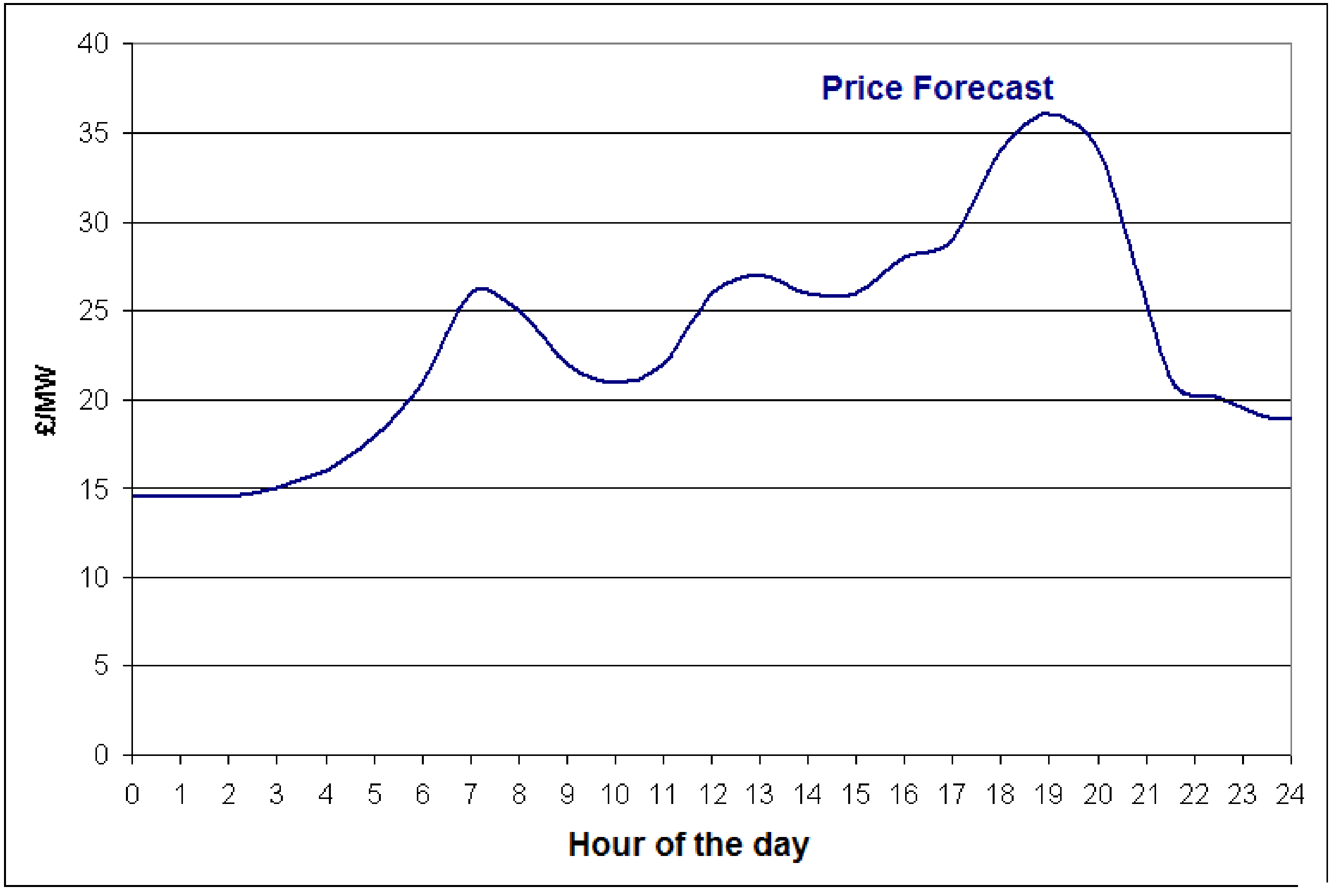
- Each player uses a different algorithm to forecast prices (based on shared information)

Players Price Forecasting Methods

- 5-Day Rolling Average
  - $\overline{LMP}_{h,d} = \frac{1}{5}\sum_{i=1}^{5} LMP_{h,d-i}$, *for weekdays* $\overline{LMP}_{h,d} = \frac{1}{2}\sum_{i=1}^{2} LMP_{h,d-i}$, *for weekends*
- Linear Regression Using System Reserve Margin (SRM)
  - $\overline{LMP}_{h,d} = a_1 \times SRM_{h,d} + a_2 \times SRM_{h,d}{}^2 + \ldots + a_n \times SRM_{h,d}{}^n$
  - Coefficients vary across simulation as new data is recorded
- Log-Linear Regression Using SRM
  - $\overline{LMP}_{h,d} = a_1 \times Log\left(SRM_{h,d}\right) + a_2 \times Log\left(SRM_{h,d}\right)^2 + \ldots + a_n \times Log\left(SRM_{h,d}\right)^n$
- Neural Network Using SRM

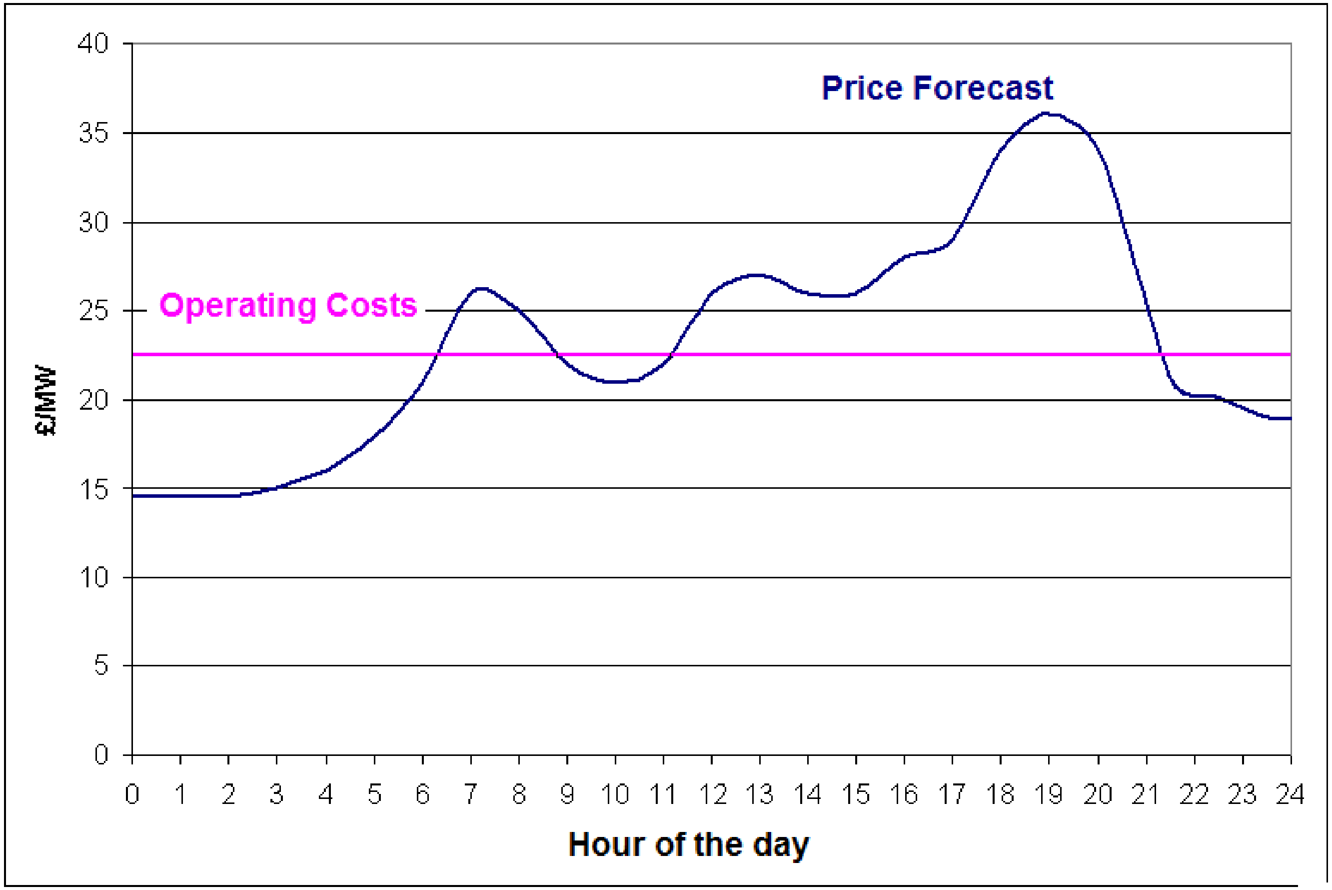
Unit Commitment Algorithm

- Generating Companies (GenCos) forecast day ahead hourly price



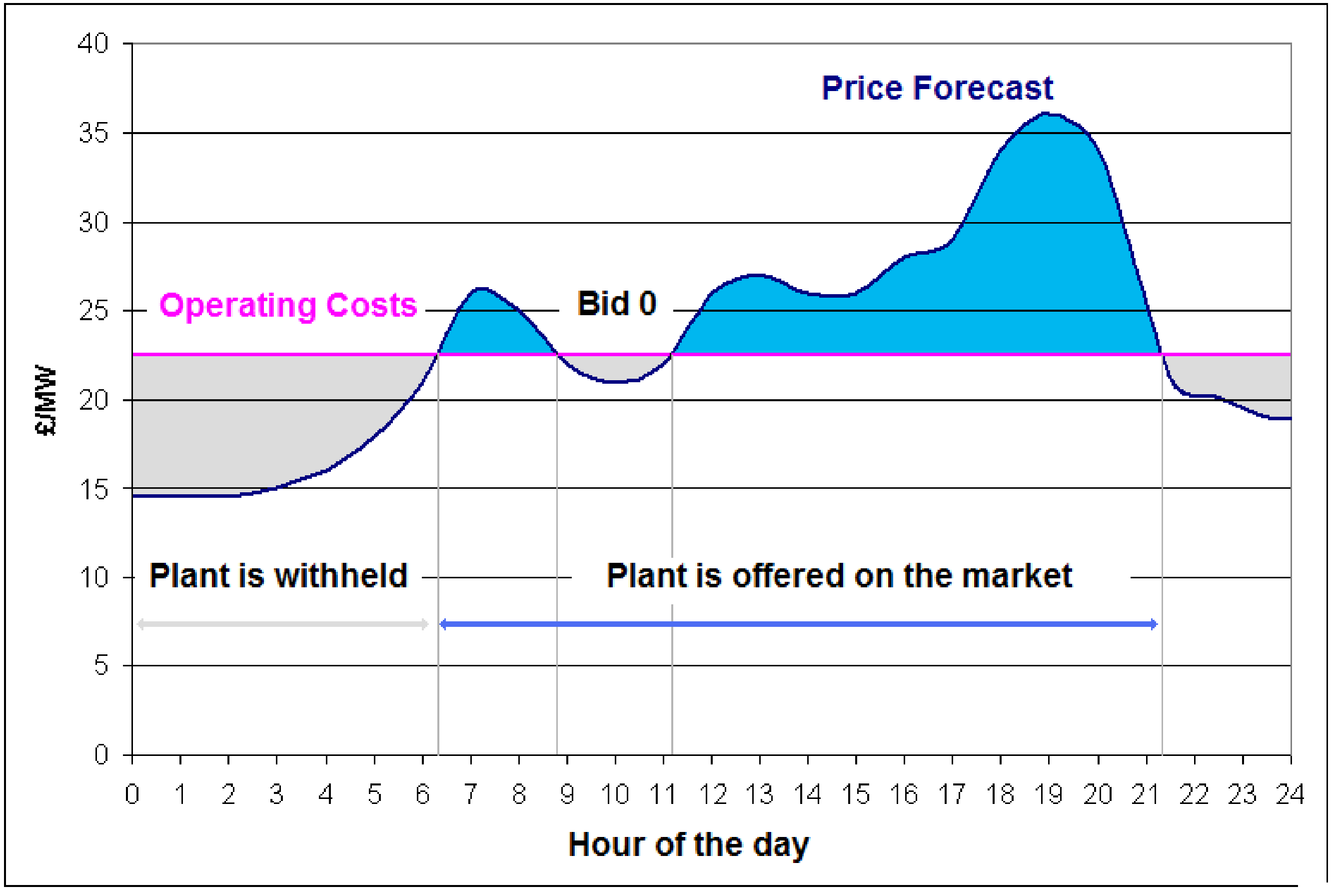
Unit Commitment Algorithm

- GenCos compare operating costs to price forecast for each plant



Unit Commitment Algorithm

- Start-up costs are taken into consideration and the optimal consideration of start-ups and shut-down is derived

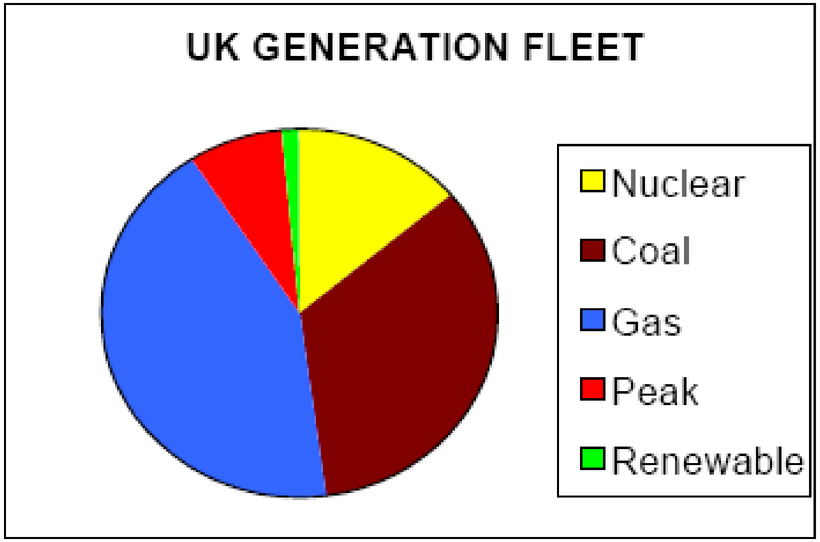


Argonne NATIONAL LABORATORY EDF

Application to the UK market

UK Market Description

- No large hydro and small interconnections with neighbours
- Total Capacity 72 GW
  - Data taken from the Department for Business, Enterprise & Regulatory Reform (BERR)
- Seven main players represented
- Network constraints not modelled



Results

Argonne NATIONAL LABORATORY

edf CHANGER L'ÉNERGIE ENSEMBLE

Forecast Accuracy --No Unit Commitment--

Comparison of actual price with forecasted price

- Mean Average Percentage Error (MAPE) across all day

	Hist Av	L D1	L D2	L D3	L D4	L D5	L D6	L D7	LL D1	LL D2	LL D3	LL D4	NN
MAPE	4.3%	5.0%	4.7%	5.5%	4.8%	3.8%	3.7%	3.7%	4.7%	5.2%	3.8%	3.6%	5.1%

- MAPE for Peak and Baseload

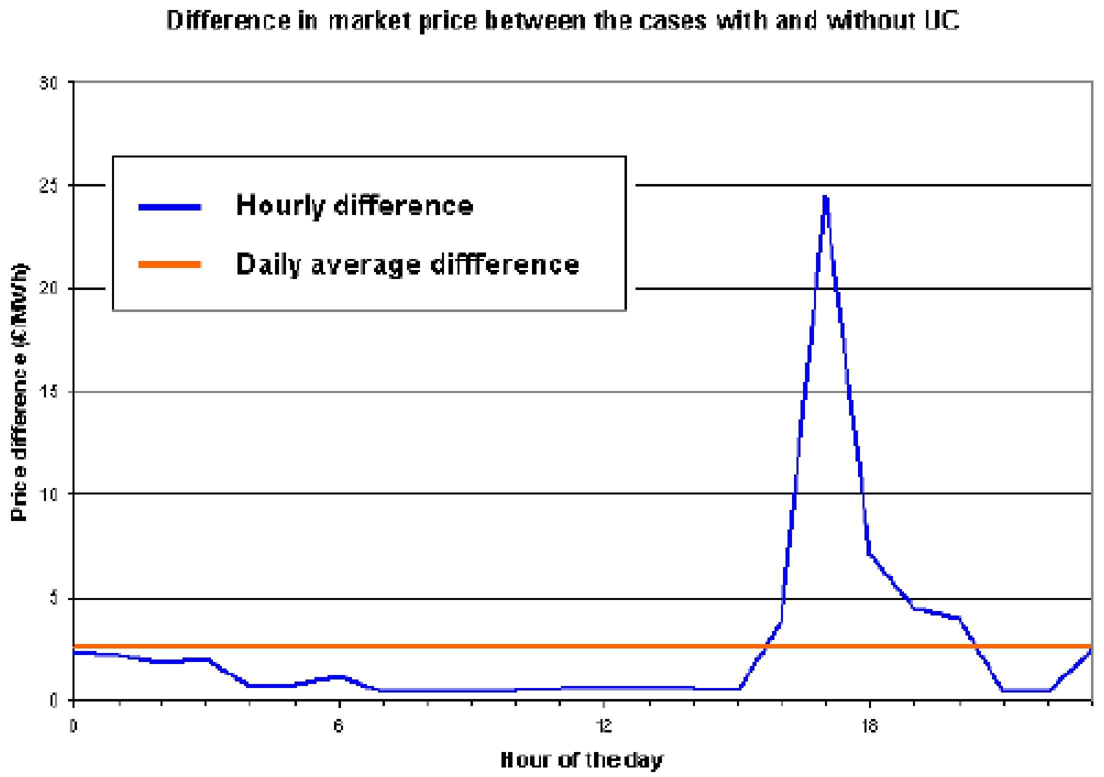
		Hist Av	L D1	L D2	L D3	L D4	L D5	L D6	L D7	LL D1	LL D2	LL D3	LL D4	NN
Peak	MAPE	10.9%	7.6%	7.3%	7.3%	5.9%	5.1%	4.5%	3.9%	6.9%	6.2%	4.1%	4.1%	7.7%
	Ranking	13	11	10	9	6	5	4	1	8	7	3	2	12
Base-load	MAPE	3.3%	4.7%	4.3%	5.2%	4.6%	3.6%	3.6%	3.6%	4.3%	5.0%	3.7%	3.5%	4.8%
	Ranking	1	10	7	13	9	3	4	5	8	12	6	2	11

- Log Linear regression outperforms Linear one
- Higher order polynomial regressions are more “sensitive”
- Methods ranking vary between Base and Peak (Most “sensitive” methods have better peak-forecasting power but performs badly at night time)

Impact of unit commitment on marginal price

Here, all GenCos use different forecast methods

- Decentralised, price-based unit commitment tend to increase prices, especially during peak hours



Impact of Accuracy on System Price

- We consider the impact of Unit Commitment on system price for different sets of forecasting methods for the GenCos

	Base Case	Hist. Average	LD 2	LL D3
Average forecast error (%)	5.3%	12.8%	6.0%	5.2%
Average SMP (£/MWh)	25.4	26.1	25.5	24.8

- Forecast errors tend to increase prices as dispatch are non-optimal
- The use of separated unit commitment by all players reduces forecast accuracy as information is not shared by all players

Impact for a single independant GenCo

Here, major GenCos do not use UC. Only an independent GenCo who owns 3 gas plants resorts to price-based UC

- Unit Commitment can increase profits, if forecast is accurate enough

	No UC	Hist. Average	LD 2	LLD 4
Average forecast error (%)	N/A	11.40%	7.40%	3.57%
Monthly Profit (£)	1.7E+04	9.1E+03	2.4E+04	3.4E+04

- A certain degree of risk-taking can increase profits as well as decrease system price by improving plant dispatch

Minimum Target Profit	No UC	40%	10%	1%	0%	-1%	-3%	-7%	-20%	-40%
Monthly Profit (£)	1.7E+04	1.0E+03	2.3E+04	2.6E+04	2.7E+04	2.7E+04	3.2E+04	2.9E+04	2.0E+04	1.7E+04

Conclusions

Argonne NATIONAL LABORATORY

EDF
CHANGER L'ÉNERGIE ENSEMBLE

Conclusions

- For GenCos relying heavily on day-ahead market to sell their electricity, ensuring optimal plant dispatch is a key issue
- Price-based unit commitment may result in sub-optimal dispatch due to the discrepancy between forecasted and real price
- Good forecast accuracy is essential to an efficient dispatch
- Allowing flexible bidding rules for GenCos may reduce total system costs as well as system marginal price

Thank you for your attention