Efficient Solution of Optimal Multimarket Electricity Bid Models

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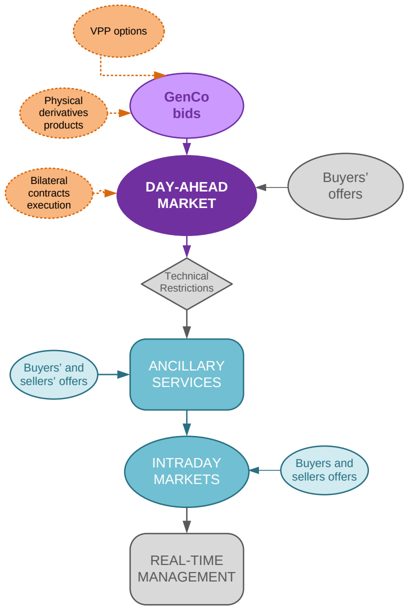
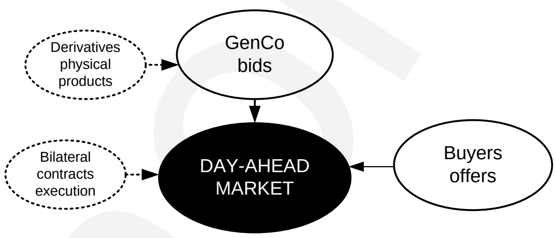
Iberian Electricity Market



- The MIBEL (created in 2007) joins Spanish and Portuguese electricity system.
- It complements the previous mechanisms of the Spanish Electricity Market with a Derivatives Market.
- It established a fully competitive framework for the generation of electricity, with a set of market mechanism centralized and managed by the *market operator*.
- It included a Day Ahead Market, a Reserve Market and a set of Intraday Markets to which the generation companies (GenCo) could submit their sell bids.

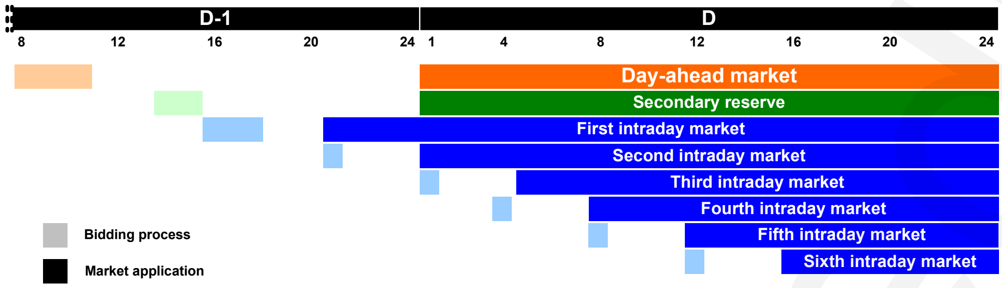
The GenCo's optimal DAM bid problem

The GenCo's optimal DAM bid problem considers a *Price-Taker* generation company with:



- A set of thermal generation units, I, with quadratic generation costs, start-up and shut-down costs and minimum operation and idle times.
- Each generation unit can submit sell bids to the 24 auctions of the DAM.
- A set of physical futures contracts, F, of energy L_j^F $j \in F$.
- A pool of bilateral contracts B of energy L_k^B, $k \in B$.

Sequence of markets in the MIBEL



Ancillary Services

Participants send bids to potentially increase or decrease the matched energy of the matched units in the day-ahead market.

Intraday Markets

It works exactly as the day-ahead market does, except that the GenCo can participate as a buying as well as selling agent.

Integration of the market sequence in the day-ahead market bid

- Our starting point is the DAM optimal bid models developed in Corchero et al. 2011 and Heredia et al. 2010 and 2011.
- In the present work the market sequence is integrated in the DAM bid model with the following considerations:
  - A GenCo that participates in the ancillary services always bids the AGC capacity of the unit and, the only decision to be optimized is whether it participates or not.
  - In order to participate in the ancillary services the generation output of a unit along two successive intervals must be constant.
  - Just the first intraday market is considered.

Objectives of the model

A multistage stochastic programming model has been developed to decide:

- the optimal bid in the day-ahead market abiding by the MIBEL rules
- the optimal economic dispatch of the physical futures and bilateral contract among the thermal units
- the optimal unit commitment of the thermal units

maximizing the expected profit of the market sequence

taking into account the commitments deriving from futures contracts and bilateral contracts, the technical production constraints, the sequence of markets rules and the stochasticity of the DAM, reserve and intraday market prices.

OMEB: Variables

First stage variables: for each period t and unit i

- The unit commitment variables: $u_{ti} \in \{0, 1\}$.
- The instrumental price offer bid variables: q_{ti}.
- The scheduled energy for futures contract j variables: f_{tij}.
- The scheduled energy for bilateral contract variables: b_{ti}.

Second and third stage variables: for each t, i and scenario s

- Total generation: g^s_{ti}
- Matched energy in the day-ahead market: p^s_{ti}
- Reserve market related variables: $r^s_{ti} \in \{0, 1\}$
- Intraday market related variables: m^s_{ti}

OMEB: Model description

OMEB

Max Expected benefit of the markets' sequence

s.t.

Physical futures and bilateral contract coverage

Day-ahead market rules

Reserve market rules

Intraday market rules

Unit commitment

Nonanticipativity

Mixed integer quadratic multistage stochastic program.

Perspective cuts: Motivation

- The OMEB model is a Mixed-Integer Quadratic Program (MIQP), which is difficult to solve efficiently, especially for large-scale instances.
- A possibility is to use a polyhedral outer approximation of the quadratic generation cost function $f(g,u)$

$$f(g,u) = c^q g^2 + c^l g + c^b u$$

by means of perspective cuts (Frangioni and Gentile 2006), so that this problem can be solved as a Mixed-Integer Linear Program (MILP) by general-purpose MILP solvers.

Perspective cuts: Implementation

The numerical experiments solved instances of the OMEB problem with three different procedures:

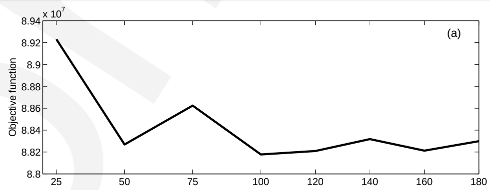
- **MIQP1** The MIQP solver of Cplex 12.1
- **MIQP24** The MIQP solver of Cplex 12.1 with multithreading (24 threads).
- **PCF** The MILP solver of Cplex 12.1 were the dynamic generation of PCs was implemented by means of the `cutcallback` procedure.

Method	Time (h)	c.v.	b.v.	Constraints	S
MIQP1	$120h30'^{*}$	145.680	48.240	381.796	200
MIQP24	$8h45'$	145.680	48.240	381.796	200
PCF	$2h58'$	261.857	48.240	641.151	200

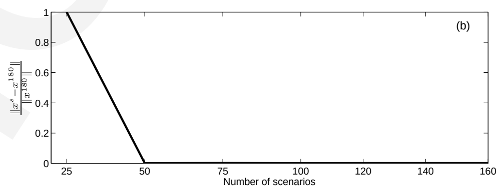
* Execution aborted
Fuji RX200 S6 (2 x CPUs Intel Xeon X5680 Six Core / 12T 3.33 GHz, 64Gb RAM)

OMEB: Scenario Set

- 50 scenarios from a reduced equiprobable set of historical data of DAM, reserve and intraday market prices.



Objective function

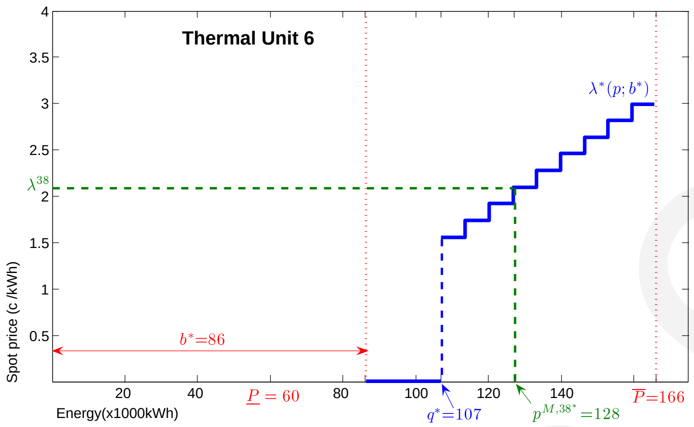


First-stage variables

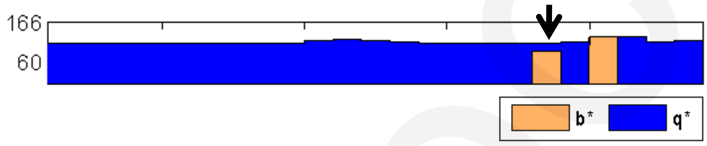
$\lvert S\rvert$	c.v.	b.v.	CPU(s)	Objective function	$\frac{\lVert x^s - x^{200}\rVert}{\lVert x^{200}\rVert}$
25	19680	6240	210	89230500	1,000
50	37680	12240 745	88268300	0,001	
75	55680	18240	1664	88624200	0,002

24 hours, 9 thermal units, 3 FCs, 1 BC portfolio. CPU Time: Perspective cuts with CPLEX.

Results (1/3): optimal bidding curve

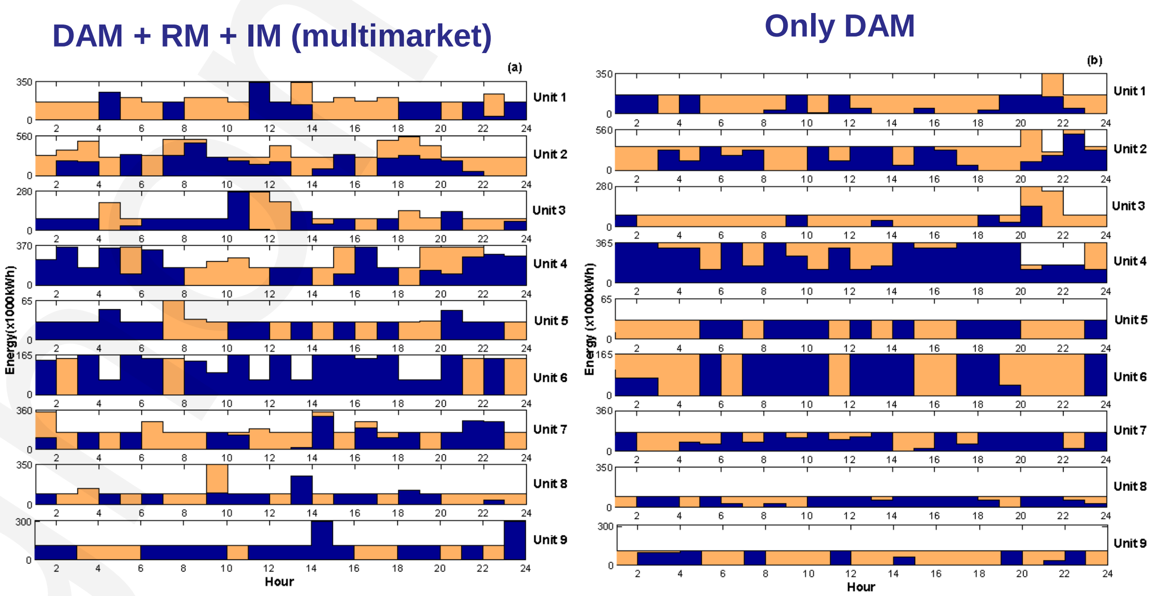


Optimal bidding curve for thermal unit 6 at interval 18



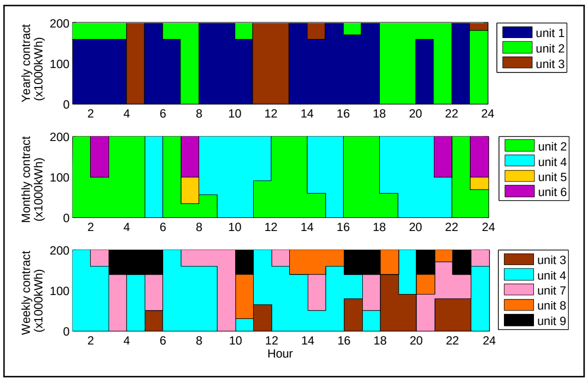
Bilateral and futures coverage of unit 6 along 24h

Results (2/3): commitment of the bilateral and future contracts

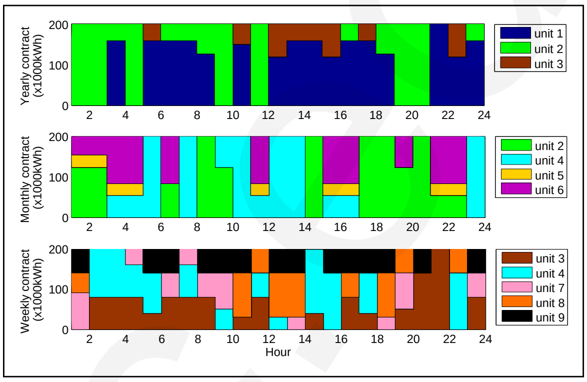


Blue: bilateral contracts; orange: future contracts

Results (3/3): Economic dispatch of the futures contracts



Economic dispatch of FCs
(market sequence)



Economic dispatch of FCs
(only day-ahead market)

Conclusions

- It has been developed a model for the optimal DAM bid with Futures and Bilateral Contracts taking into account the Ancillary Services and the first Intraday Market.
- The optimal solution determines the optimal instrumental price bidding and the optimal economic dispatch of the BCs and the FCs.
- The numerical experiments show how the Ancillary Services and the Intraday Market affect both the optimal bid to the DAM and the optimal allocation of the energy of the Bilateral and Futures Contracts among the generation units.