Optimal Day-Ahead Bidding in the MIBEL's Multimarket Energy Production System

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Iberian Electricity Market: MIBEL

Derivatives Market

Physical Futures Contracts
Financial and Physical Settlement. Positions are sent to OMEL's Mercado Diario for physical delivery.
Financial Futures Contracts
OMIClear cash settles the differences between the Spot Reference Price and the Final Settlement Price

Bilateral Contracts

Organized markets
- Virtual Power Plants auctions (**EPE**) - Distribution auctions (**SD**) - International Capacity Interconnection auctions - International Capacity Interconnection nomination
Non organized markets
- **National** BC **before** the spot market - **International** BC **before** the spot market - **National** BC **after** the spot market

Day-Ahead Market

Day-Ahead Market
Hourly action. The matching procedure takes place 24h before the delivery period. Physical futures contracts are settled through a zero price bid.

Characteristics of Physical Futures and Bilateral Contracts

Base Load Futures Contract

- A *Base Load Futures Contract* consists in a pair (L^{FC}, λ^{FC})
  - L^{FC}: amount of energy (MWh) to be procured each interval of the delivery period.
  - λ^{FC}: price of the contract (c€/MWh).

Bilateral Contracts

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Integration of the futures and bilateral contracts in the DAM bid

The energies L^{FC} and L_t^{BC} must be integrated in the MIBEL's DAM bid respecting the two following rules:

1. If generator i contributes with f_{itj} MWh at period t to the coverage of the FC j, then the energy f_{itj} must be offered to the pool for free (instrumental price bid).
2. If generator i contributes with b_{it} MWh at period t to the coverage of the pool of BCs, then the energy b_{it} must be excluded from the bid to the day-ahead market. Unit i can offer its remaining production capacity $\overline{P}_i - b_{it}$ to the pool.

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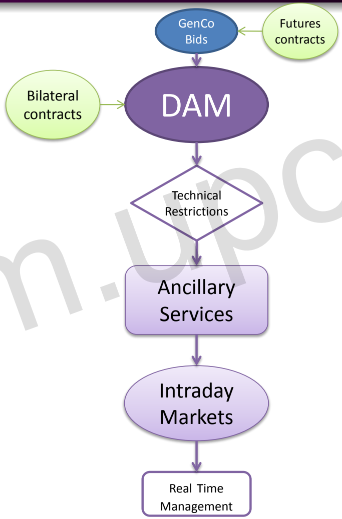
Electricity Market Description



Characteristics of the sequence of markets in the MIBEL

Ancillary Services

- Takes place after the DAM
- The participants send bids to potentially increase or decrease the matched energy of the matched units in the DAM.
- If a bid is matched the unit must be available to increase or decrease its generation level in a given interval.

Intraday Markets

- It consists of 6 consecutive markets. It takes place just before and during the delivery day.
- It works exactly as the DAM, except the GenCo can participate as a buying or selling agent.

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Integration of the market sequence in the DAM bid

The market sequence is integrated in the DAM bid model with the following considerations:

1. A GenCo that participates in the Ancillary Services always bid the AGC capacity of the unit and, the only decision to be optimized is whether it participates or not.
2. In order to participate in the Ancillary Services the change in the generation output of a unit between two successive intervals must be within certain limits.
3. Just the first Intraday Market is considered.
4. In a specific interval, a unit can only participate as a selling or buying agent, not both.

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Problem definition

The objective of the study is to decide the:

- DAM instrumental price bid
- optimal economic dispatch of the physical futures and bilateral contract among units

maximizing the expected market sequence profits taking into account the commitments deriving from futures contracts and bilateral contracts, the technical production constraints and the stochasticity of the electricity prices.

Variables

First stage variables:

- $q_{it} \geq 0$: Instrumental price offer bid in the DAM
- $f_{itj} \geq 0$: Scheduled energy for futures contract j
- $b_{it} \geq 0$: Scheduled energy for bilateral contracts

Second and third stage variables:

- p_{it}^{s}: Total generation
- $p_{it}^{M,s}$: Matched energy in the DAM
- $r1_{it}^{s}, r2_{it}^{s}, r3_{it}^{s} \in \{0, 1\}$: Ancillary Services related variables
- $w_{it}^{s} \geq 0, y_{it}^{s} \geq 0$: Energy of the sell or purchase bid for the Intraday Market
- $v_{it}^{s} \in \{0, 1\}$: Intraday Market related binary variable

Day-Ahead Market

DAM constraints

Matched energy bounded between the instrumental price offer and the total available energy

$$p_{it}^{M,s} \geq q_{it} \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$p_{it}^{M,s} \leq \overline{P}_i - b_{it} \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

Limits to the instrumental price bid quantity

$$q_{it} \geq \underline{P}_i - b_{it} \qquad \forall i \in I \quad \forall t \in T$$

$$q_{it} \geq 0 \qquad \forall i \in I \quad \forall t \in T$$

$$q_{it} \geq \sum_{j|i \in U_{jt}} f_{itj} \qquad \forall i \in I \quad \forall t \in T$$

Bilateral and Futures Contracts

Futures contracts constraints

$$\sum_{i \in U_{jt}} f_{itj} = L_j^{FC} \quad \forall j \in F \quad \forall t \in T$$

Bilateral contracts constraints

$$\sum_{i \in I} b_{it} = L_t^{BC} \quad \forall t \in T$$

$$b_{it} \leq \overline{P}_i \quad \forall i \in U_t \quad \forall t \in T$$

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Market sequence (I/III)

Ancillary services constraints (I/II)

$$\Delta p^s_{it} = p^s_{it} - p^s_{i(t-1)} \quad \forall i \in I \quad \forall t \in T \setminus \{1\} \quad \forall s \in S$$

Ancillary services model:

Constant generation level: If $\Delta p^s_{it} \in [-k, k] \Rightarrow r1^s_{it} = 1$

Ramping up: If $\Delta p^s_{it} \geq k \Rightarrow r2^s_{it} = 1$

Ramping down: If $\Delta p^s_{it} \leq -k \Rightarrow r3^s_{it} = 1$

Market sequence (II/III)

Ancillary services constraints (II/II)

$$(k - \Delta p_{it}^{s}) \geq M^{R}(r1_{it}^{s} - 1) \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$(k + \Delta p_{it}^{s}) \geq M^{R}(r1_{it}^{s} - 1) \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$(\Delta p_{it}^{s} - k) \geq M^{R}(r2_{it}^{s} - 1) \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$(\Delta p_{it}^{s} + k) \leq M^{R}(1 - r3_{it}^{s}) \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$r1_{it}^{s} + r2_{it}^{s} + r3_{it}^{s} = 1 \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

Market sequence (III/III)

Intraday Market constraints

$$w_{it}^{s} \leq M^{I} v_{it}^{s} \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$y_{it}^{s} \leq M^{I}(1 - v_{it}^{s}) \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

$$y_{it}^{s}, w_{it}^{s} \geq 0 \qquad \forall i \in I \quad \forall t \in T \quad \forall s \in S$$

Total generation and non-anticipativity constraints

Total generation constraints

$$p_{it}^{s} = b_{it} + p_{it}^{M,s} - y_{it}^{s} + w_{it}^{s} \qquad \forall t \in T \quad \forall i \in U_t \quad \forall s \in S$$

$$\underline{P}_i - g_i r1_{it}^{s} \leq p_{it}^{s} \leq \overline{P}_i - g_i r1_{it}^{s} \qquad \forall t \in T \quad \forall i \in U_t \quad \forall s \in S$$

Non-anticipativity constraints

$$p_{it}^{s} = p_{it}^{\hat{s}} \qquad \forall s, \hat{s} : (\lambda^{Ds} = \lambda^{D\hat{s}}) \quad \forall t \in T$$

$$r1_{it}^{s} = r1_{it}^{\hat{s}} \qquad \forall s, \hat{s} : ((\lambda^{Ds}, \lambda^{Rs}) = (\lambda^{D\hat{s}}, \lambda^{R\hat{s}})) \quad \forall t \in T$$

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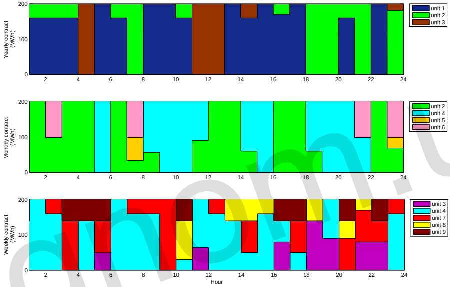
Objective function

$$\max_{p,q,f,b} \sum_{t\in T} \sum_{i\in U_t} \sum_{s\in S} P^s \Big[\lambda_t^{Ds} p_{it}^{M,s} + \lambda_t^{Rs} r1_{it}^s g_i + \\ + \lambda_t^{Is} y_{it}^s - \lambda_t^{Is} w_{it}^s - c_i^l p_{it}^s \Big]$$

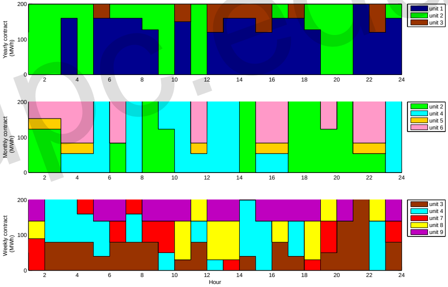
Case Study characteristics

- Real data from the Spanish Market about the generation company and the market prices.
- 10 thermal generation units from a Spanish GenCo with daily bidding in the Spanish Market.
- Market prices from January 1^{rst}, 2008 to January 1^{rst}, 2009.
- Scenario set built from the reduction of available historical data.
- Model implemented and solved with AMPL/CPLEX

Results: energy committed to futures contracts

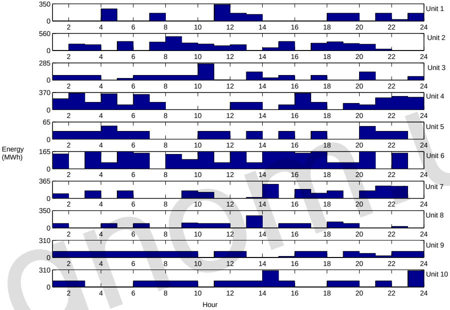


Multimarket



DAM

Results: bilateral contracts settlement



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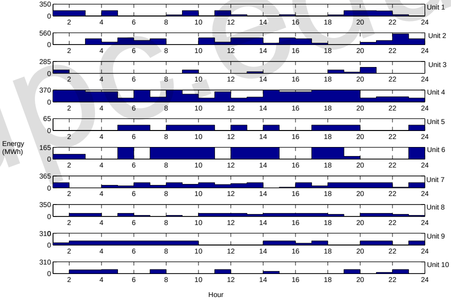

DAM

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.

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