A stochastic approach to the decision support procedure for a Generation Company operating on Day-Ahead and Physical Derivatives Electricity Market

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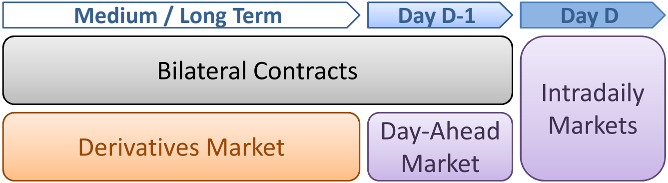
July 6, 2008

Electricity Market Description



Derivatives Market

Physical Futures Contracts
- Financial and Physical Settlement - Positions are sent to DAM for physical delivery
Financial Futures Contracts
- Only Financial Settlement

Bilateral Contracts

Non organized markets
- Bilateral contracts before the spot market - Bilateral contracts after the spot market - International bilateral contracts
Organized markets
- Virtual Power Plants auctions - Distribution auctions - International Capacity Interconnection

Day-Ahead Market

Day-Ahead Market
- Hourly action - Matching procedure 24h before the delivery period - Coordination with other organized markets

Characteristics of Physical Futures Contracts

Main characteristics

- Base load
- Physical and financial settlement
- Delivery period: years, quarters, months and weeks

Definition

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

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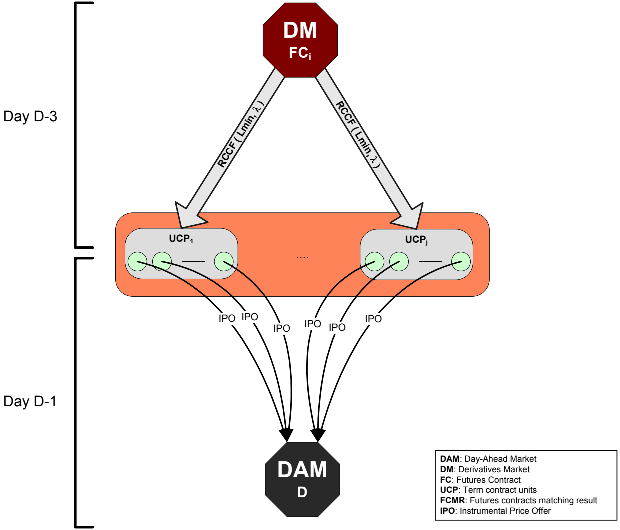
Physical Futures Contracts and Day Ahead Market



Characteristics of the Generation Company

Generation Company

- *Price-taker:* its offer do not alter market prices
- Daily participation on the Day-Ahead Market and the Derivatives Market
- With committed Bilateral Contracts

Generation System

- Hydro plants
- Thermal plants

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Problem definition - PENDENT

The objective of the study is to decide:

- the optimal economic dispatch of the physical futures contract among the units
- the optimal unit commitment and scheduled production

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

Problem definition

Model characteristics

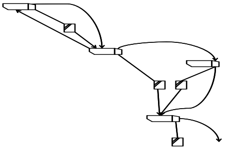
- Two-stage stochastic linear programming model
- Set of thermal generation units, I
- Set of hydro generation units, K
- Optimization horizon of 24h, T
- Set of physical futures contracts, F
- Set of DAM selling price scenarios, $\lambda_t^s \ t \in T, \ s \in \mathcal{S}$
- Set of DAM buying price scenarios, $\mu_t^s \ t \in T, \ s \in \mathcal{S}$

Variables

Hydro system : $\forall t \in T,\ \forall i \in I,\ \forall j \in J$

Arc capacities: q_{it}

Basin capacities: v_{jt}



Thermal system : $\forall k \in K,\ \forall t \in T$

Unit commitment: $\gamma_{kt},\ \alpha_{kt},\ \beta_{kt}$

Production level: p_{kt}

Market and Futures Contracts: $\forall t \in T$

Bided quantities: $sell_t,\ buy_t$

Futures settlement: $gh_{itf}\ \forall i \in I\ \forall f \in F,\ gt_{ktf}\ \forall k \in k\ \forall f \in F$

Hydro system constraints $\forall t \in T$, $\forall i \in I$, $\forall j \in J$

Arc capacities: $0 \leq q_{it} \leq \overline{q}_i$

Basin capacities: $0 \leq v_{jt} \leq \overline{v}_j$

Min final water vol: $v_{jT} \geq \underline{v}_{jT}$

Mass balance: $v_{it} = v_{jt-1} + F_{jt} + \sum_{i \in I} A_{ij} q_{it}$

Thermal system constraints $\forall k \in K$

Unit commitment

$$\gamma_{kt-1} + \alpha_{kt} = \gamma_{kt} + \beta_{kt} \ \forall t \in T$$

$$\gamma_{kt} = 1 \quad \text{if } \gamma_{k0} = 1 \quad 1 \leq t \leq ta_k - nh_k$$

$$\gamma_{kt} = 0 \quad \text{if } \gamma_{k0} = 0 \quad 1 \leq t \leq ta_k - nh_k$$

$$\sum_{\tau=t+1}^{\min(t+ta_k-1,T)} \gamma_{k\tau} \geq \alpha_{kt} \min(ta_k - 1, T - t) \quad 1 \leq t \leq T$$

$$\sum_{\tau=t+1}^{\min(t+ts_k-1,T)} \gamma_{k\tau} \leq (1-\beta_{kt}) \min(ts_k - 1, T - t) \quad 1 \leq t \leq T$$

Operation control

$$p_{kt} - p_{kt-1} \leq \delta u_k + \alpha_{kt}(vsu_k - \delta u_k) \quad 1 \leq t \leq T$$

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Market and Futures Contracts: $\forall t \in T$

Market and Bilateral Contracts

$$\sum_{i \in I} k_i q_{it} + \sum_{k \in K} p_{kt} + buy_t = car_t + sell_t \quad 1 \leq t \leq T$$

Futures Contracts

$$\sum_{i \in Ig_f} k_i gh_{itf} + \sum_{k \in K_f} gt_{ktf} = L_f \quad \forall f \in F,\ 1 \leq t \leq T$$

$$\sum_{f \in F} k_i gh_{itf} \leq uh_{it} \quad \forall i \in Ig_f,\ 1 \leq t \leq T$$

$$\sum_{f \in F} gt_{ktf} \leq ut_{kt} \quad \forall k \in K_f,\ 1 \leq t \leq T$$

$$0 \leq uh_{it} \leq k_i q_{it} \quad \forall i \in Ig,\ 1 \leq t \leq T$$

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Objective function

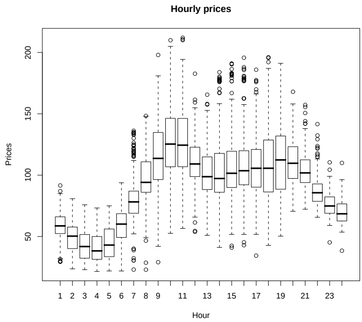
$$\min \sum_{\forall t \in T} \left[\sum_{\forall s \in S} P_s (\lambda_{ts} sell_{ts} - \mu_{ts} buy_{ts}) - \sum_{k \in K} csu_k \alpha_{kt} + csd_k \beta_{kt} + c_k(p_{kt}) \gamma_{kt} \right]$$

Case Study characteristics

- Real data from the Italian Market about the generation company and the market prices.
- Market prices from January 1^{rst}, 2008 to January 1^{rst}, 2009. Day in study January 26^{th}, 2009.
- 17 thermal generation units and 12 hydro generation units from a Italian generation company with daily bidding in the Italian Market.
- Model implemented and solved with GAMS/CPLEX
- CPU time using a SunFire V20Z with two processors AMD Opteron at 2.46Hz and 8Gb of RAM memory.

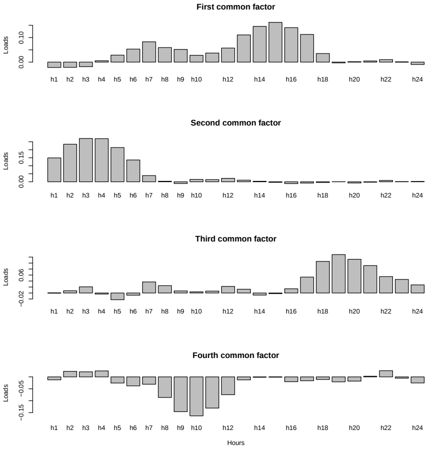
Uncertainty characterization

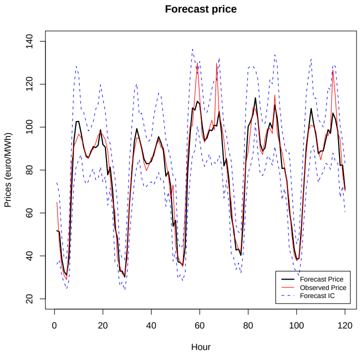
- Uncertainty source: DAM Price, λ_{ts}, characterized as a time series. Prices for the day in study must be forecasted.
- Price scenario forecasting method:



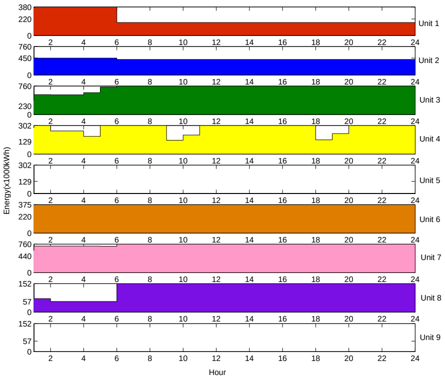
1. 24 time series are considered
2. Factor model estimation
3. Forecasting model specified as a linear multiple regression model with the factors as predictors
4. Price scenario simulation

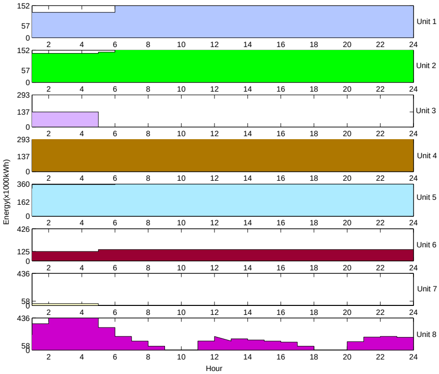
Common factors loading





Results: energy committed to futures contracts





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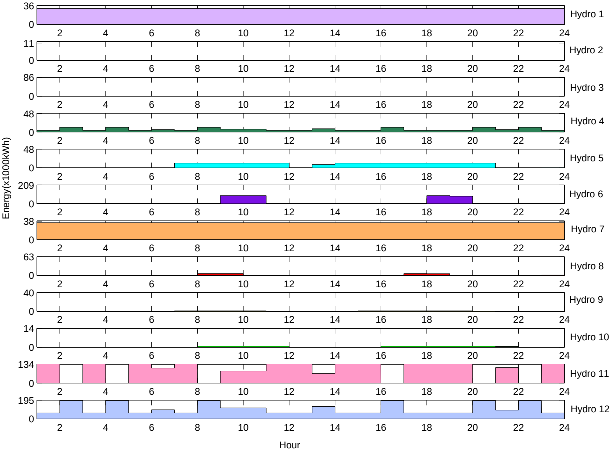
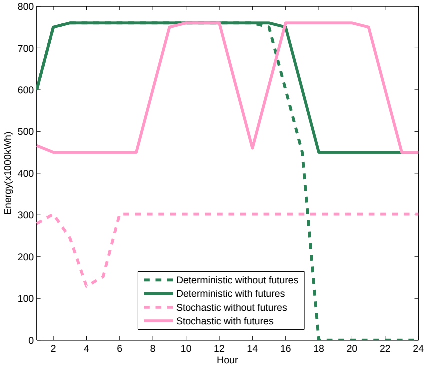
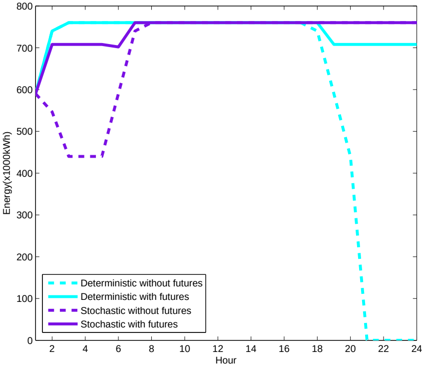


Results: optimal generation level





Conclusions

- It has been introduced the electricity market price stochasticity into the optimization model which coordinates the participation in the Day-Ahead and the Derivatives Market.
- It has been identified a factor model for the Italian Electricity market price and it has been built an scenario set suitable for the two-stage stochastic model.
- It has been solved the model with the data of an Italian Generation Company with hydro and thermal units and futures and bilateral contracts.

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