ANALYIS OF BID PRICING & LOAD ASSIGNMENT POLICIES IN AN ELECTRICITY MARKET THROUGH AN INTEGRATED OPTIMIZATION-SIMULATION MODEL

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Overview

An integrated simulation-optimization model is developed for the modeling and analysis of a decentralized electricity market. It is aimed to investigate the impact of bid pricing decisions (of the electricity suppliers), load assignment policies (of the system operator), generator characteristics (of the generators in the system) on electricity prices, load assignments, generator profits and the supply–demand balance. The model is designed such that it can be used for market design as well as investment planning, being capable to evaluate electricity production technology and capacity choices.

The Power User Agents (UA), the Power Generator Agents (GA) and the System Operator (SO) are the three major components of the integrated model. The individual hourly demands of the UA are assumed to be inelastic and are aggregated into overall hourly demands with daily and seasonal demand patterns. Part of the demand may be met through bilateral agreements with the GA.

The objective of GA is to maximize (own) profit. So, they try to increase both the price and amount of electricity they sell to the system. For this purpose for each hourly period of the next day, they bid prices to the SO within the framework of their technical constraints and past performance guided bidding strategies. If they have remaining capacity left, they may offer bids for hourly slices of the current day, if the SO declares such a need.

The SO is the central planner agent, which tries to satisfy the overall demand of UA at minimum cost. The SO considers, i) the set of outstanding bids (together with their prices, quantities and offered time periods) from the GA, ii) UA's aggregate hourly demand quantities, iii) amount of demand to be satisfied by bilateral agreements. The SO determines hourly electricity prices (Day Ahead Prices) & the "Day Ahead Schedule" of all GA for the next day; it then posts the schedule to the GA.

If scheduled & offered electricity supply does not cover the realized demand (due to random demand fluctuations & supply unavailabilities), the SO may make a call for bids for the hourly slices of the same day within the framework of "Real Time Balancing". This additional bid taking & settlement generate "System Marginal Prices" of the current day

Methods

According to Ventosa and Baillo (2005), optimization models, simulation models and equilibrium models are the three major trends to electricity market modeling. In this research linear optimization modeling is deployed to mimic the bid evaluation and load assignment policies of the system operator, while agent based simulation modeling is deployed to mimic the bidding behavior of the electricity suppliers (generators) and demand characteristics of the customers.

The optimization model is geared to handle the "day ahead planning" function of the System Operator, within the framework of a "Balance and Settlements System" similar to the one discussed by Bagdadioğlu and Odyakmaz (2009). The simulation model is a multi-agent model, reflecting the profit maximization aims and bidding strategies of generators. Its purpose and functioning are similar to the Bower and Bunn (2000) model, the Binn (2004) model (which also uses learning processes to improve generator bidding strategies under repetitive bidding) and the Guerci and Ivaldi (2005) model (which focuses on the day ahead market of the Spanish Power Exchange in a multi-agent framework). The power of agent based simulation was also acknowledged by Batten (2000) as a "computational technique that can reflect learning processes and mimic the structure and clearing mechanism of the market, with a high level of detail, and is useful for understanding market behavior".

The implementation is made on a hypothetical market with 10 generators and with total supply exceeding total maximum demand by 10%. The profile of the generators, as well as the general profile of the aggregate random demand is selected as to mimic the Turkish electricity market. Various scenarios are developed to investigate the effects of, i) conservative versus aggressive pricing strategies in day-ahead planning, ii) high versus low demand, iii) conservative versus aggressive pricing strategies in real-time planning, iv) implementing different bidding strategies.

Results

Some of the observations made and results obtained are as follows:

- Day Ahead Price (DAP) is lower than System Marginal Price (SMP) at all times (Figure 1).
- Weaker winds & lower water levels lead to lower generation capacities in summers, thus affecting higher prices.
- Profit levels are proportional to capacity (Figure 2).
- Large & low cost hydros lead the profit race until the dry summer months, at which time large natural gas plants' profitabilities dominate.
- Profits show greater variability in large plants than in small ones (Figure 2).
- DAP & SMP prices, capacity utilizations, profits of generators are higher in "High Demand" environment.
- In "High Demand" environment, "Aggressive Pricing Behavior" leads to higher SMP levels, while "Aggressive Behavior" does not lead to any significant changes in SMP in "Low Demand" environment.
- In "Low Demand" environment, "Conservative Pricing Behavior" leads to higher profit, capacity utilization & market share levels in the related generators.
- Natural gas plants are most impacted by demand level changes, while wind plants are least impacted.
- Under High Demand, "Aggressive Pricing" leads to higher profits, compared to "Conservative Pricing".

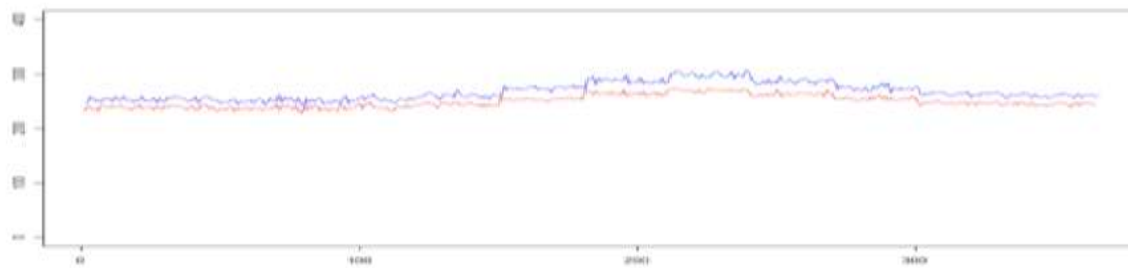

Figure 1 Average Day Ahead Prices and System Marginal Prices

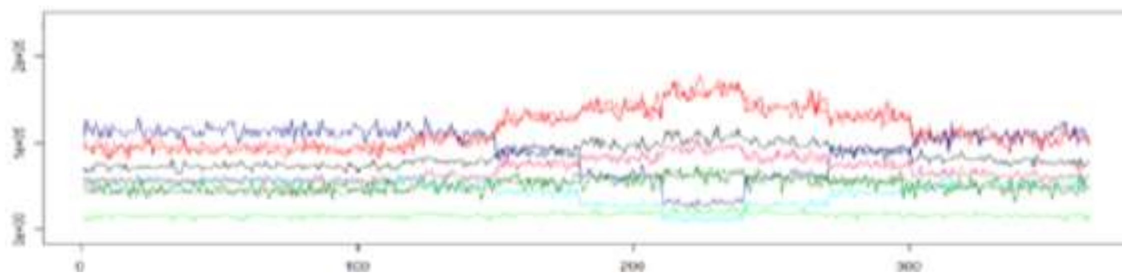

Figure 2 Average Daily Profits of Power Plants

Conclusions

The results reveal that the above-mentioned factors have substantial impact on market dynamics. Power and capabilities of the simulation-optimization model is demonstrated (even under hypothetical data). If such a model is deployed by generators, they would benefit through, i) better understanding the strong & weak aspects of their generator assets and their future investment options, ii) fine tuning their bidding strategies, iii) better understanding the capabilities & power of the SO and their competitors.

If such a model is deployed by the SO, it would benefit through, i) better understanding of its self power & power of generators, ii) recognizing the weaknesses of the market, iii) fine tuning the bidding mechanisms and rules and investment incentives, with an eye to lower and more stable electricity prices.

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