Bidding Behavior Analysis of Generating Companies in Iran's Electricity Market

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***Abstract*— Modeling and analyzing behavior of market participants is a crucial task towards optimized design and operation of electricity markets. In this paper, we study bidding behavior of generating units in Iran's electricity market using publicly available data such as hourly demand, weighted average price and bids of generator units. Structure of power market in Iran allows each generator to bid its capacity in several steps/blocks. First, this paper analyzes and discusses about the number of steps offered to the market. Due to the nature of Pay As Bid (PAB) markets, we expect that the bidding behaviors of the companies highly depend on the grid's demand; therefore, as the next step, effects of demand value on distribution of bids in off-peak, shoulder and peak hours are investigated. Finally, using bidding data of the generating units, we try to explain why price peaks and load peaks are not coincident in summer days of 2011.**

Keywords-component; bidding behavior; bidding strategy; aggregate supply curve; pay as bid market; bids distribution.

I. INTRODUCTION

A. Motivation

Modeling and analyzing behavior of market participants' is a crucial task towards optimized design and operation of electricity markets. Generating companies, consumers and Independent System Operators (ISOs) are the main parties of all electricity markets, whose interactions form financial and technical features of power systems. ISOs are responsible for providing fair, transparent and competitive market environment for all participants. Therefore, they should analyze participants' behavior and monitor market signals to identify any deviations from market's primary objectives and rules. ISOs (in some markets, regulatory boards) constantly modify market rules to introduce new features into the market such as demand response programs, renewable energy integration, environmental policies, etc. Since effects of enacted rules on market may appear only after a long period, it is beneficial for ISOs to build up models of market participants to test rules prior to enforcing.

B. Literature review

Several researches have been conducted to model and analyze bidding behavior of generating companies. Reference [1] analyzes empirical bidding data of generating companies in Australia's National Electricity Market (NEM). It investigates on-peak and off-peak behavior of generating companies separately, and categorizes them into inactive, moderately active and active players, based on their responses to changes in market conditions. In order to identify application of capacity withholding strategies, [1] compares capacity commitments of generating units in off-peak and on-peak hours. Investigations confirm that large companies often withhold their capacities during peak-hours.

Reference [2] proposes a model to analyze bidding behavior of generating companies in New York's (NYISO) day-ahead electricity market. 325 generating companies are classified into five groups based on their bid prices; then a statistical model is proposed to simulate their bidding behavior. Using the proposed method, market clearing price for several demand assumptions are discussed.

Observations on bidding patterns in England and Wales' electricity market confirms that generating companies act strategically in the market i.e. they bid above their marginal costs [3]. Reference [4] studies market power in California electricity market in year 2000. Comparing bidding patterns of the five largest players in 2000 with previous years (1998 and 1999), it concludes that generating companies applied noticeable market power, which caused market prices to raise.

Reference [5] measures effects of enacted laws by regulatory board in Spanish electricity market between 2002 and 2005. It indicates that enforced regulations changed bidding patterns of market participants such that prices decreased dramatically.

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C. Contributions

In this paper, we analyze bidding behavior of generating units in Iran's electricity markets which has the following interesting characteristics: (i) it is still moving towards maturity; therefore, some of the generating units behave immaturely. (ii) in contrast to previous studies, market clearing mechanism of Iran is pay as bid (PAB); thus, some special features can be identified in the bidding behavior of the market participants. (iii) demand side is rather inactive in Iran's market; therefore, analyzing bidding behavior of generating companies might sufficiently explain market features, such as price signals.

D. Paper organization

This paper is organized as follows: In section II an overview of Iran's electricity market is presented and available data for the public are introduced. Section III compares distribution of bids in several demand levels. Section IV tries to justify certain behavior in price signal of the market, using bidding data of the generating companies. Finally, paper is concluded in section V.

II. IRAN'S ELECTRICITY MARKET

Founded in 2004, Iran Grid Management Company (IGMC) is the independent system operator (ISO) in Iran. This company is in charge of operating, monitoring and providing competitive environment in Iran's electricity market [6] - [7]. In 2011, 450 generating units with total capacity of 60 thousand megawatts were active.

Although bilateral contracts are allowed in the market, majority of power is transacted through the day-ahead power pool [8]. Therefore, analyzing generating companies' behavior in the power pool provides an almost thorough overview of the total networks transactions.

Iran's electricity market is cleared based on pay-as-bid auction rules [9]. Clearing mechanism in electricity markets is either Uniform Pricing (UP) or Pay-As-Bid (PAB) [10]. In the UP mechanism all winning generating units are paid at the same price (Market clearing price). In contrast, PAB indicates that each winning unit is paid at its own bidding price. Bidding strategies of generating companies are affected by clearing mechanism [11]. In PAB markets, such as Iran, generating companies should forecast maximum accepted price of the market and bid slightly less than it. As a result, aggregated supply functions of the PAB markets are higher than that of UP markets (Fig. 1).

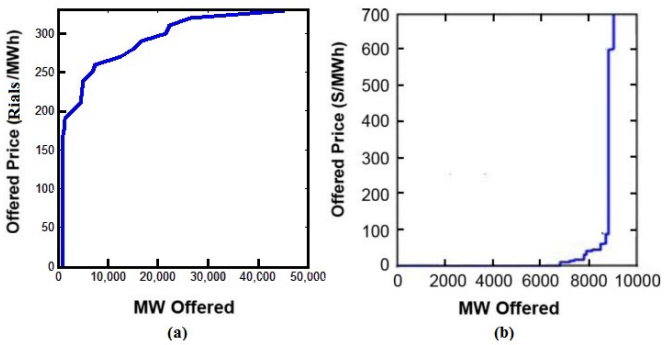

Fig 1. Comparing effects of market clearing mechanism on aggregate bidding behavior of generating companies (a) Iran supply curve (Pay as bid) (b) Alberta Supply curve (Uniform) [12]

Regulations of Iran's electricity market impose a price cap on bids of generating units, which prevents price spikes in the market and reduces possibility of exercising market power [7]. Obviously, average market price would never exceed the price cap. In 2011, the price cap was 330 Rials/KWh.

A. Data

In this paper, we use Iran's electricity market data such as hourly demand, market price and generating companies' bids in 2011-2012 (available at [13]). Published Bidding data are masked, i.e., name of the bidding companies are not available to the public. Each company is assigned a code which changes every day; therefore, bidding behavior of a specific generating company cannot be tracked over a period of time.

Due to the nature of PAB markets, a single market clearing price does not exist in Iran's electricity market. Thus, IGMC publishes several price signals including: (i) minimum accepted price, (ii) maximum accepted price and (iii) weighted average price (WAP) considering transmission constraints. WAP is the average of the accepted price blocks weighted by the amount of its accepted power [8]. Ideally, the most valuable signal to market participants is the maximum accepted price. However, due to transmission constraints, some companies are able to exercise market power. As a result, maximum accepted price is often reported to be the market's price cap [14]. Therefore, practically, the weighted average price (WAP) is the most valuable price signal in Iran's electricity market, which we use in our analysis in the rest of the paper.

III. BIDDING STEPS

Since power producers incur variable cost for electricity generation, majority of electricity markets provide stepwise bidding for market participants. Power producers divide their capacities into several steps/blocks/segments and bid for each separately [15]. Maximum number of bidding segments is different in each electricity market according to their respective rules. For instance, California and "England & Wales" allow 16 and 3 segments respectively [15-16]. In Iran, similar to Australia, 10 steps are allowed.

Our analysis on bidding data shows that some of the generating units allocate last steps of bids for identifying

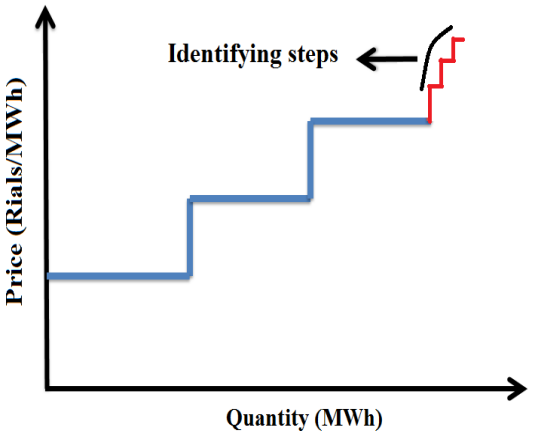

Fig 2. A sample bidding curve of a generating company: *identifying steps* (red) are used to identify maximum accepted price of the market

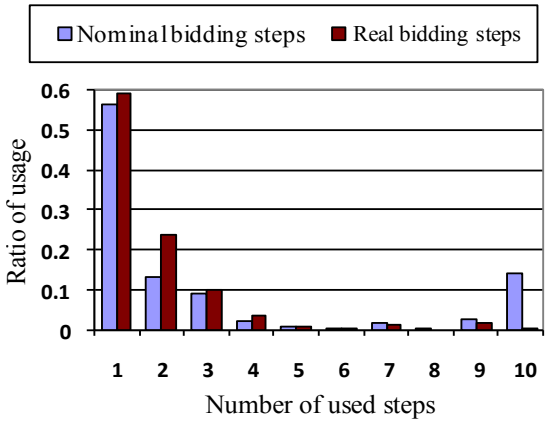

Fig 3. Number of used steps in bidding procedure by generating companies, Jan 2012

maximum accepted price of the market in their region; they assign small portion of their total capacity to these "*identifying steps*" so that their profit is not affected if these steps are not accepted in the market. Identifying steps have price values up to the price cap. Generating companies are motivated to bid these identifying steps because, as mentioned earlier, maximum accepted price data, provided by IGMC, are not practically useful. The most expensive accepted identifying step indicates the maximum price that the generating unit could have bid to the market and won. Moreover, generating units will understand if they have market power. Due to technical and physical constraints of the network, IGMC is forced to dispatch specific generating units, even if they bids higher than others (sometimes even as high as the price cap). Such generating units can bid identifying steps to realize their market power and increase their profit dramatically. (Fig. 2)

Figure 3 demonstrates number of steps that generating units used for bidding in January 2012. Nominal bidding steps (blue) are total number of steps bid to the market, while real bidding steps (red) are total number of steps subtracted by the number of identifying steps. 15 % of generating units nominally bid with 10 steps, but if we do not take identifying steps into account, almost no companies use 10 steps. Therefore, it might be inferred that 15% of generating units wisely try to identify market status.

It seems that most of the market participants bid with few number of steps. Reference [15] expresses that in pay-as-bid (PAB) markets, the more steps used in bidding procedure, the higher profits generating units could make because more bids can be manipulated and generating units may exercise market power more easily. Since About 70% of the generating units bid with only 1 or 2 steps, we infer that most of the generating companies do not acquire appropriate bidding strategies and Iran's electricity market rules are not exploited to the full extent.

IV. Distribution of Bids for Different Demands of the Grid

Since the income of the generating companies in PAB markets directly corresponds with their own bids (not the market clearing price) market participants should forecast the maximum accepted price and bid accordingly. Therefore we expect bid blocks to be concentrated around a certain price which generating companies believe to be the maximum accepted price. Moreover, since all bids less WAP are ideally accepted by the market, it seems irrational to bid all or parts of the capacity at prices much less than WAP. Price bids less than WAP might be made by risk averse companies or companies with inaccurate understanding of the market status.

Figure 4 illustrates aggregate bids of generating companies for off-peak, shoulder and on-peak hours of a certain day. For instance, first part of the figure shows that in hour 7, 2500 MWh of power (10% of the demand) are bid to the market at 60 Rials/KWh. As we expect from PAB markets, aggregate behavior of the companies highly depends on the demand. As demand raises, weighted average price (WAP) and distribution of bids tend to move towards the right part of the graph (high price values).

Base-load generators seem to bid uneconomical in off-peak hours. In hour 7 (as an off-peak hour), although WAP is 200 Rials/KWh, almost one third of the required demand can be bought at a price even less than 120 Rials/KWh. Therefore, one might infer that in off-peak hours, base-load generators are unreasonably risk averse which lead WAP to decrease even further.

As the grid's demand increase, generating companies show more reasonable bidding behavior; bids are concentrated around the WAP. For instance, in peak hour of 21, almost all the power is bid in a 10-Rial-neighborhood of the WAP.

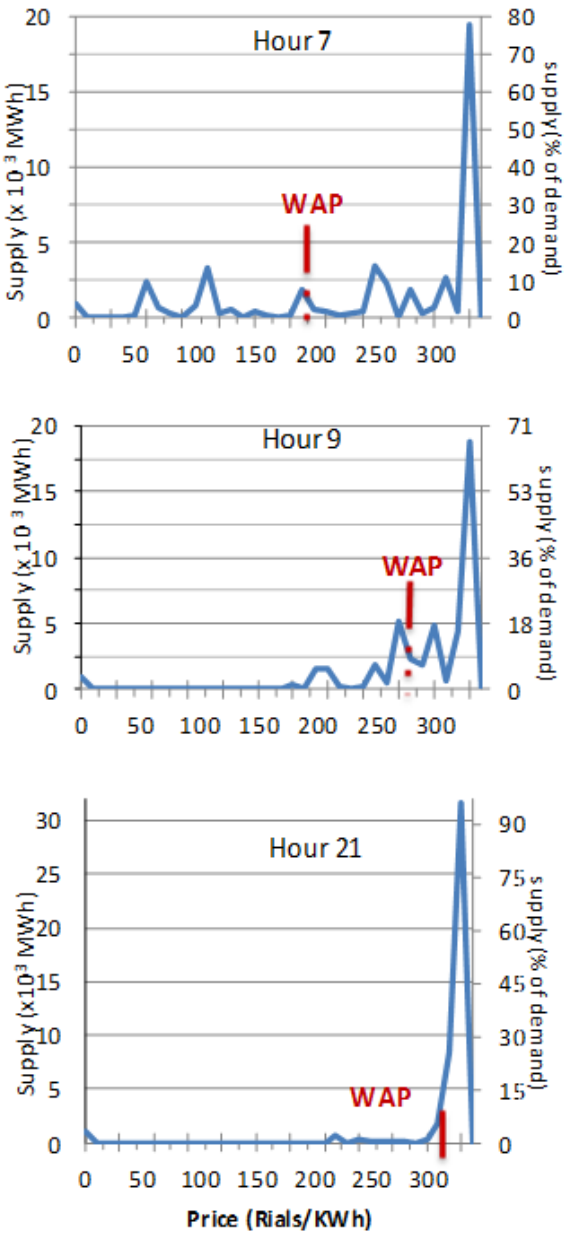

Fig 4. Distribution of bids for base-load (hour-7, 26 GWh), medium load (hour 9, 26 GWh) and peak-load (hour 21, 33 GWh), September 20, 2011 (WAP: weighted average price)

V. EFFECTS OF BIDDING BEHAVIOR ON PRICE TRENDS

In this section we introduce two characteristics of price-demand pairs observed in the summer of 2011. In order to draw an application for analyzing bidding data, we try to explain these characteristics by investigating bidding behavior of the generators in the target period. In our investigations, we use weighted average price (WAP) as the market price, because it is the cost that will be incurred by the consumers.

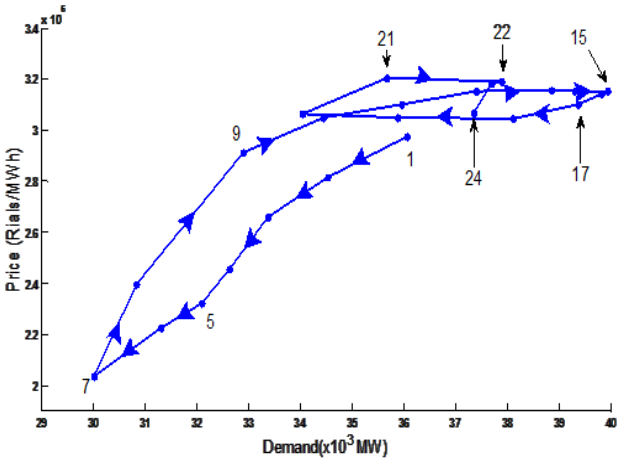

Fig 5. Price-quantity plot, July 25 2011 (Numbers represents hours in the day)

Figure 5 illustrates price-bid pairs of Iran's electricity market in a summer day. As the day starts (hour 1), demand gradually decreases up until hour 7 (lowest demand in the day). Demand peaks at hour 15 and a local maximum is observed in hour 22. Two main characteristics of price-demand relationship are:

1- Against expectations, price peak and demand peak are not coincident; Price peak and demand peak occur at hour 21 and 15 respectively.

2- Hysteresis behavior throughout the day: for the same demand values, several market prices are observed. It seems that for the same demand values, price is higher in the hours that demand is increasing in comparison to hours that demand is decreasing.

The same patterns are observed in the majority of summer days.

Since in Iran's electricity market consumers (demand side) does not participate in the market bidding procedure, the main reason for these characteristics must lie in the bidding behavior of the generating companies. Therefore, we compare bids of the price peak (hour 21) and the demand peak (hour 15) with each other (Fig. 4). In hour 15 (demand peak) more power is bid at low price ranges (250 to 300 Rials/KWh). As a result, the power required to satisfy grid's demand is bought at less price and WAP of hour 15 becomes less than hour 21 (price peak).

Our investigations show that the bids from 250 to 280 Rials/MWh mostly belong to first step of large generating units. Capacities of these steps are close to minimum generation constraint of these units. Therefore, we can infer that owners of generating units bid this blocks cheap to avoid risk of losing in the market and incurring start-up costs. Generally it is believed that the lower the demand, the higher the risk of losing in the market's auction. Consequently, risk aversion policies are deemed to be more suitable in lower demand rates. Nevertheless, generating companies do the opposite; they demonstrate risk aversion policies in hour 15

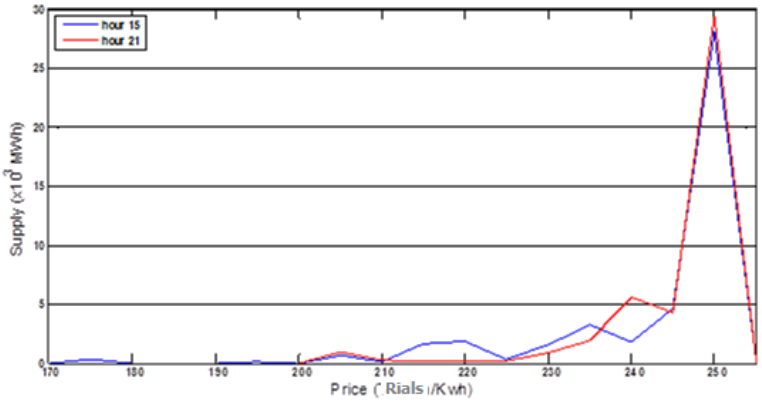

Fig 6. Distribution of bid blocks for load peak (blue, hour 15) and price peak (red, hour 21), July 25 2011

(demand peak), but such risk aversion policies are not observed in hour 21. This seemingly irrational behavior leads peak demand and peak price not to be coincident.

Explaining hysteresis pattern of the price-quantity signals requires more efforts.

VI. CONCLUSION

In this paper, we analyzed bidding behavior of Iran's generating companies and its effects on electricity market price. While 10 bidding steps are allowed in the market, majority of generating companies use less than 3 steps to bid and almost 15% of them use parts of their bidding curve to identify market's status. Distribution of bids for several hours were discussed and compared with each other. It seems that bidding behaviors of base-load generators are too cautious and uneconomical in off-peak hours. Our investigations confirms that bidding behaviors of generating companies highly depend on demand rates, as expected in pay as bid (PAB) market. Then, a hysteresis pattern in daily price-quantity pairs of the market was demonstrated. In summer days of 2011, price peaks and load peaks do not coincide. Risk aversion policies are deemed to be more suitable in lower demand values. Nevertheless, analyzing bidding data showed that generating companies do the opposite; they demonstrate risk aversion policies in load peak, but such risk aversion policies are not observed in peak price hours. This seemingly irrational behavior leads peak demand and peak price not to be coincident.

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