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A Comparison of the Results of Three Auction Experiments

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Experiments were run at Cornell University to test three different auctions: A uniform price (last accepted offer) auction, a discriminatory (pay-as-you-bid) auction and a hybrid uniform price/discriminatory auction that has been proposed by FERC as a possible interim fix to the California market. The purpose of these experiments was to try and duplicate actual behavior observed in operating markets and then design mechanisms to explain the behavior and mitigate it when appropriate.

Market Rules

The market rules faced by each of the participants in these experiments were the same except for the clearing mechanism. In each case there were six suppliers interconnected by an unconstrained network. Each supplier is provided with a given amount of capacity that is revealed to him or her at the beginning of each experiment. Each supplier's capacity is divided into five blocks each of which can be offered or withheld. An ISO selects the least expensive combination of offers to meet the system load and determines the market-clearing price (last accepted offer, discriminatory or hybrid) paid to all successful offers. The actual load is uncertain but it falls into a known range of uncertainty. Suppliers are told the load forecast and its uncertainty.

The costs of each participant's capacity have two components. The first is the operating cost in units of $/MWh for a block that is dispatched (corresponding to fuel costs). The second is a fixed standby charge in units of $/MWh for submitting an offer (corresponding to labor costs of being available to generate power). Standby costs are paid when a block is offered into the market even if it is not dispatched. Withholding blocks from the auction is the only way to avoid standby charges for those blocks. There is a reservation price (or price cap) in each market.

Since there are incentives for suppliers to withhold some capacity from the auction, it is possible that the total capacity submitted to the auction is insufficient to meet the actual load. In this case the market-clearing price is set to the highest offer submitted but any capacity withheld from the auction maybe recalled at the market-clearing price to meet the shortfall. However, a recall charge for the WHOLE block must be paid as well as the operating cost for the actual capacity purchased.

The Subjects

The subjects in all of the experiments discussed here are a group of Cornell graduate students from economics, electrical and computer engineering and computer science departments. The students were first schooled in the operation of a typical power system, then exposed to the operation of various auction mechanisms and optimization techniques, and finally lectured on earlier experiments conducted by the research group on market power and self-commitment of units. They were then subjected to a series of six experiments in order to test things like price spike behavior, the effects of withholding capacity, price responsive load and so on, using a uniform price auction. The three markets presented here were tested at the end of the semester when the students were veterans in terms of their participation in various markets. At that point they knew how to maximize profits and were adept at creating price spikes.

Results

The following series of figures show the competitive price, the actual price and the average price paid in each of the auctions. The second figure in each series shows the forecasted demand together with its uncertainty for each round, the actual demand and the total supply offered into the market. At each round the allocation efficiency of the market is computed as the cost of an optimal dispatch (i.e., all units offered at marginal cost) divided by the cost of the actual dispatch. This calculation uses only the operating costs and does not include standby or recall costs. The average efficiency is the average over a certain number of rounds in each experiment. In order to not bias the results by including early rounds where there may be some learning taking place, rounds 15-30 were used to compute average prices and efficiency for the uniform price and hybrid auctions. Rounds 26-40 were used to compute the averages for the discriminatory auction.

The preliminary results presented here provide an indication of expected behavior. More testing is needed but we are reasonably confident that the results will not be qualitatively different.

A Uniform Price Auction

In this auction each accepted offer was paid a uniform price equal to the last accepted offer. Note the price spikes that occur in Figure 1. Some of these spikes occur during a time when there is insufficient capacity offered into the market to meet demand. It is interesting to note that spikes occur during times of low load as well as during times of high load. The average price paid was $65.79/MWh when the competitive average was about $50/MWh. The offers for low cost units are close to the true costs, and a few marginal units with high offers are enough to cause price spikes. The maximum price paid was the reservation price of $100/MWh. The market efficiency was 97.7%.

A Discriminatory Auction

In this auction participants are paid their offer for accepted blocks. While price spikes continue to occur, their frequency and size are mitigated. Also, when a spike occurred the high price was paid on just a few blocks as opposed to the uniform price auction where the high price would be paid on all blocks. Therefore, the average price paid for a

spike was substantially lower. It is interesting to note that as the auction progresses, offers for low-cost blocks increase up to the level of offers for the marginal unit. The aggregate supply curve (offer curve) is almost flat as shown in Figure 5. In the end, the auction looks like a uniform price auction cleared at a higher price. For this experiment the average price was $68.54 and the market efficiency was 95.3%, almost 3% worse than the LAO auction. This is due to a large shift in dispatch as generators jockey for position in a very flat supply curve.

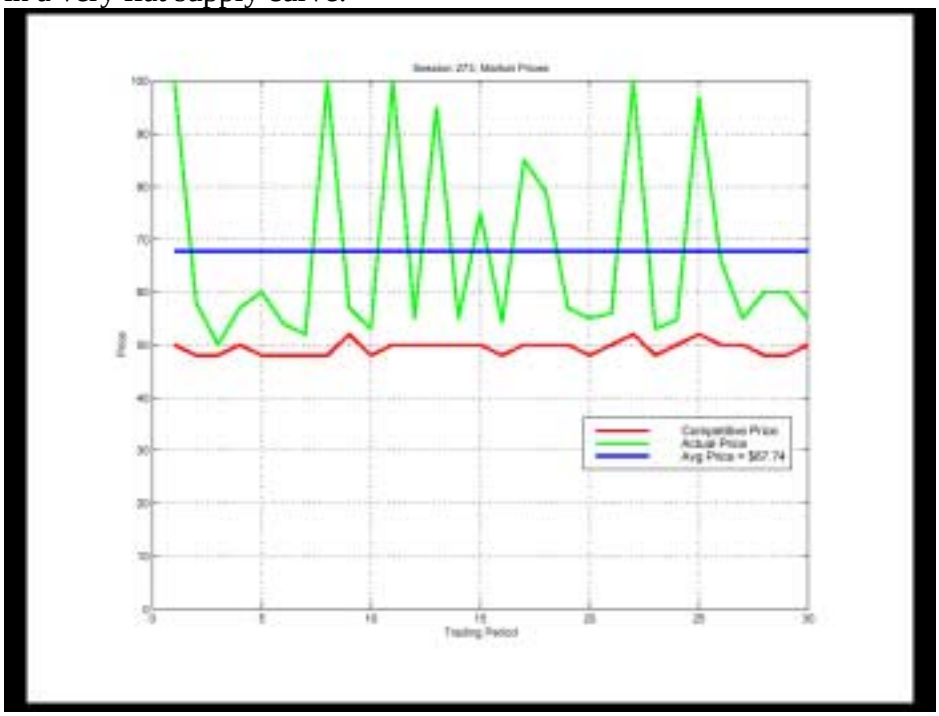


Figure 1: A uniform price LAO auction result showing competitive versus actual prices

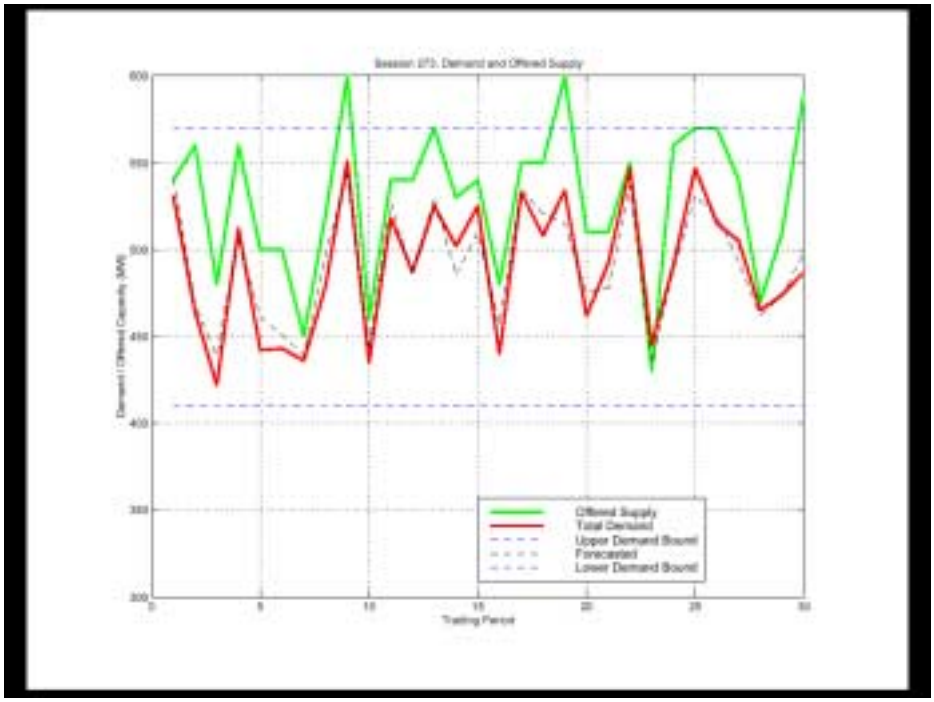


Figure 2: A uniform price LAO auction result showing actual demand vs. supply offered into the market

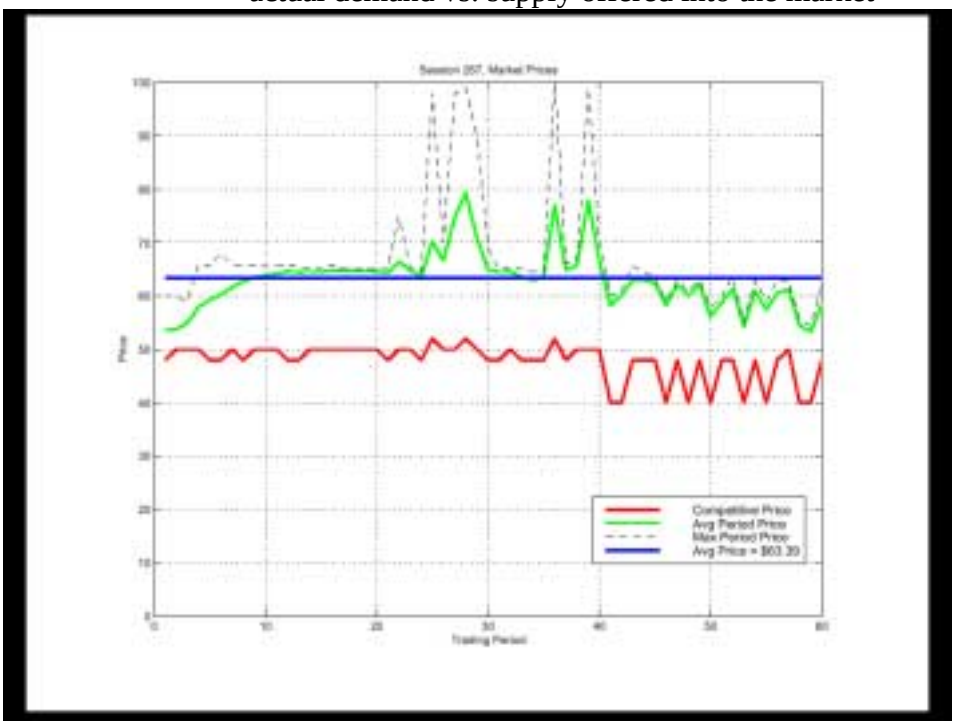
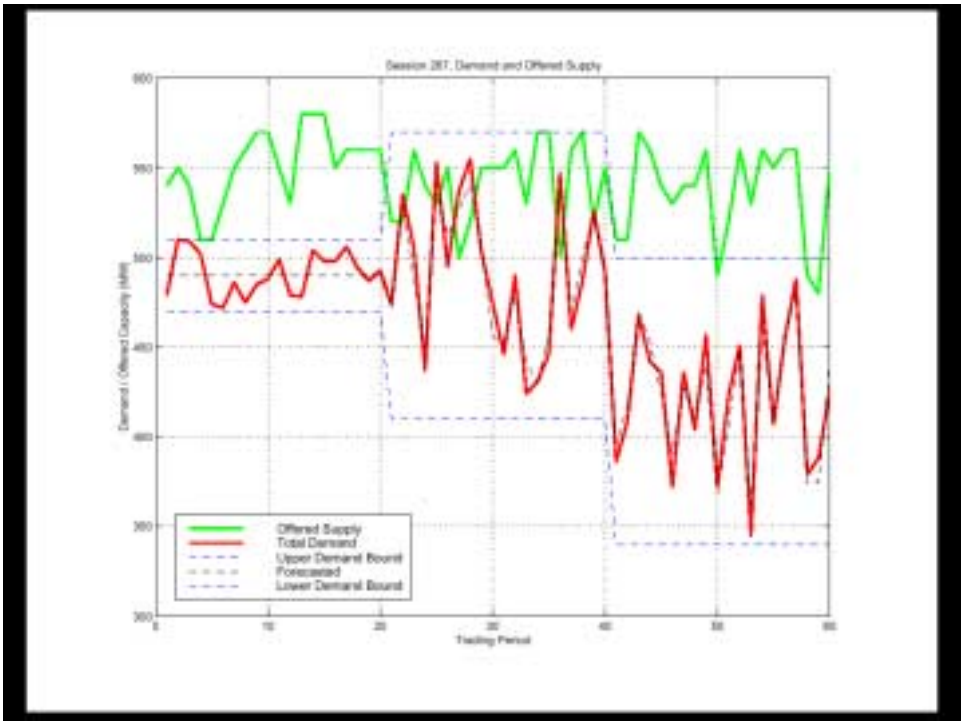


Figure 3: A discriminatory auction result showing competitive vs. actual prices



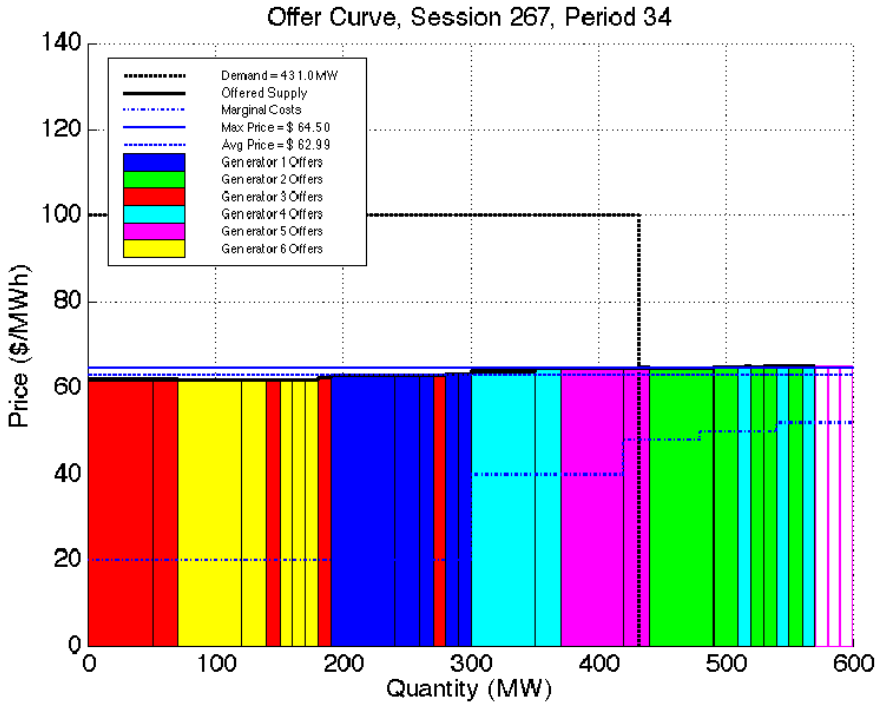


Figure 4: A discriminatory auction result showing actual demand vs. supply offered into the market

Figure 5: The offer curve 34 periods into the auction. The dotted line represents unit costs.

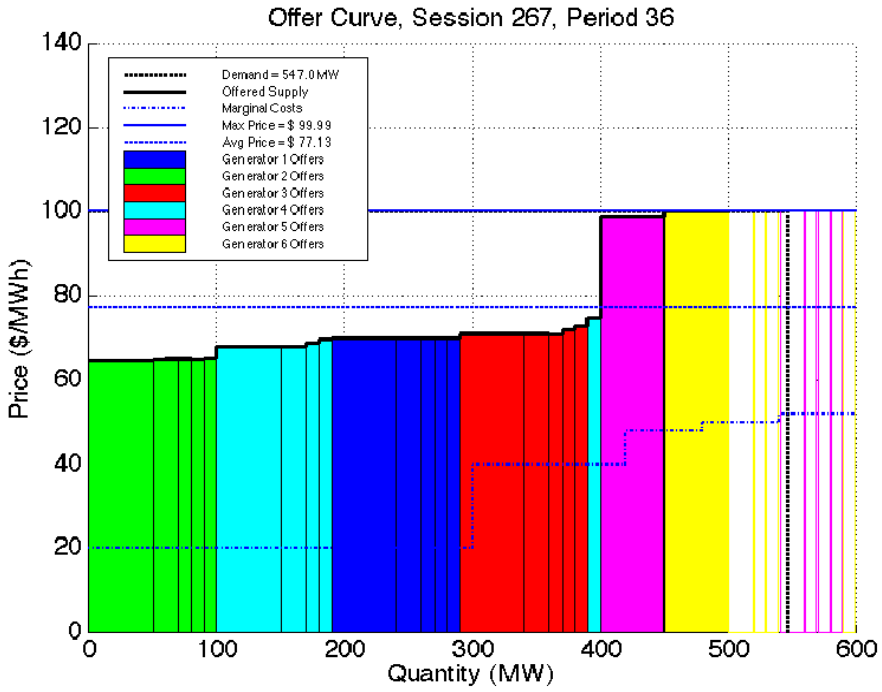


Figure 6: The offer curve for the discriminatory auction 36 periods into the auction. The dotted line represents unit costs

Some additional comments are in order concerning figures 5 and 6. Note that in addition to being flat, the offer curve in Figure 5 shows an inexpensive unit (generator 2's lowest price unit) excluded from the market in favor of a high-priced unit. We attribute this to a sudden decrease in load that was unanticipated by generator 2. That is, unit 2 expected the load to be closer to the forecast than it turned out to be. Figure 6 is interesting in that generators 1,2,3 and 4 offered all of their units as a block at a low price (but still much higher than their marginal cost) while generators 5 and 6 decided to withhold capacity. As a result, there is a substantial capacity shortage and two generators received maximum prices for their low cost blocks. Their withheld blocks were recalled at this maximum price more than compensating them for the recall charge.

A Hybrid Auction

The hybrid auction is patterned after the one proposed by FERC as a short-run remedy to the current problems of high prices in the California market. There has been a succession of lowered price caps in the California market that have been effective in lowering the peak prices paid but not necessarily the average price paid for power in California. The high prices in the summer of 2000 have created a problem for ratepayers, and it is thought that a new auction mechanism is needed. The auction tested here is a hybrid between the LAO uniform price auction and the discriminatory price auction discussed above. Basically there are two caps in the market. A LAO uniform price is paid for all capacity accepted that was offered below the lower cap of $75/MWh. Capacity offered and accepted above the lower cap (but below the maximum cap of $100/MWh) are paid

their offer. The prices for the experiment are shown in Figure 7. Figure 8 shows the actual demand vs. supply offered into the market. Note there are times even during low load when the demand exceeds supply. It appears that the participants are trying to force discriminatory prices by withholding capacity. For this experiment the average price was $78.89/MWh and the market efficiency was 95.7%. This average price is substantially higher than the LAO average price and needs to be investigated.

The offer curve in Figure 9 shows that approximately one-half of the capacity accepted in this round is being paid at or near the discriminatory cap. Note that the average price paid for this round was $87.95. While no low-priced units were excluded from this high-load period, three of the six low-price units are being paid around the cap of $100/MWh for their energy.

Conclusions

Again, the results presented here are preliminary and more testing is needed. However, they do provide an early indication of expected behavior. We believe that the results of further testing will be qualitatively the same, but we have been surprised before.

It is interesting to note that the average price paid in the hybrid auction was substantially above the prices paid in either of the other auctions while its efficiency was better than

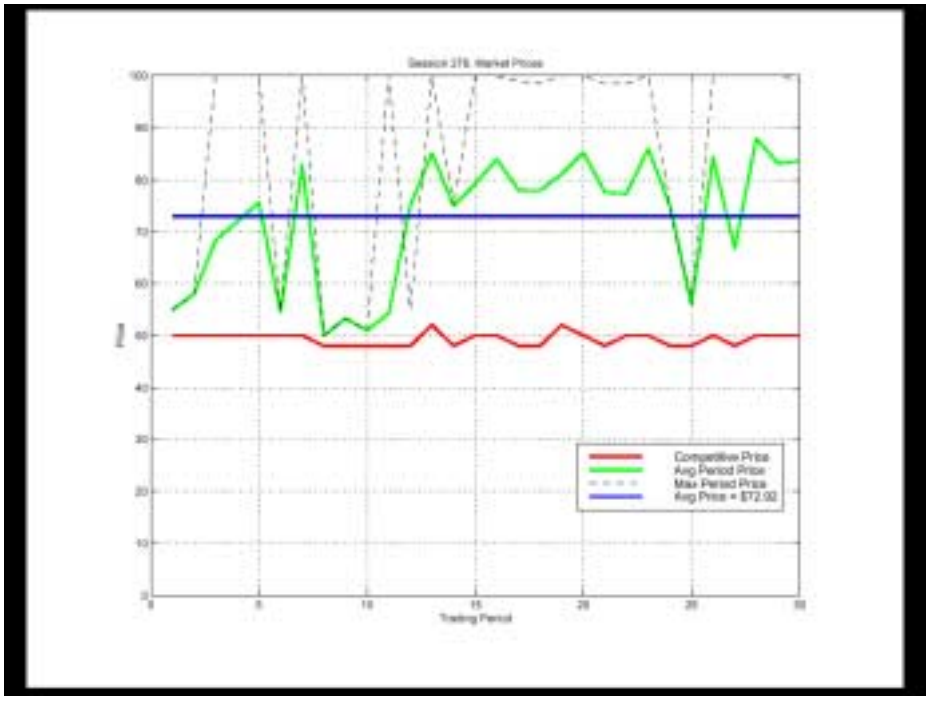


Figure 7: A hybrid auction result showing competitive vs. actual prices

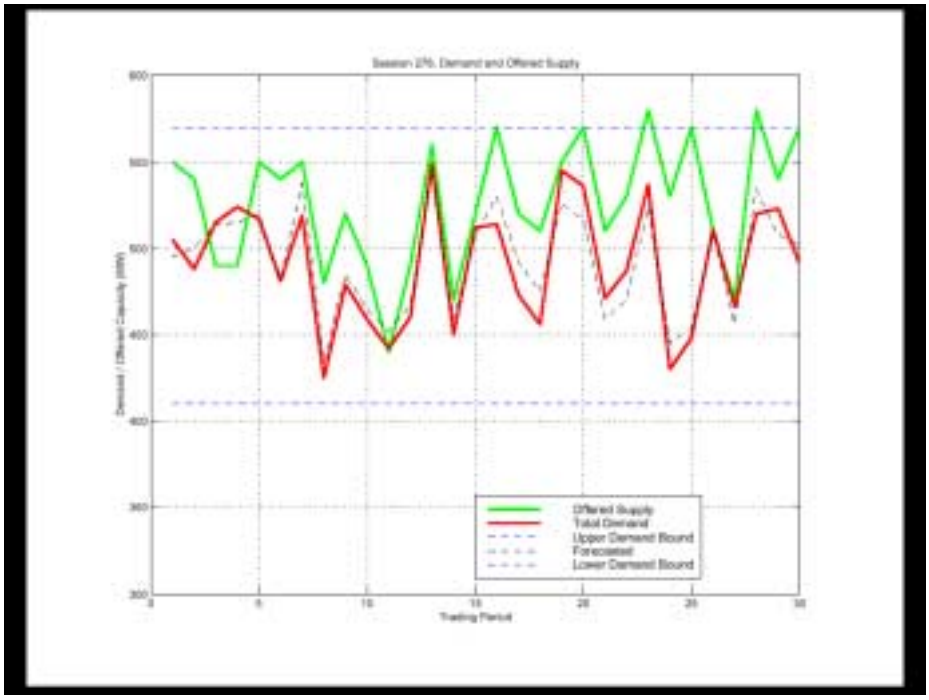


Figure 8: A hybrid auction result showing actual demand vs. supply offered into the market

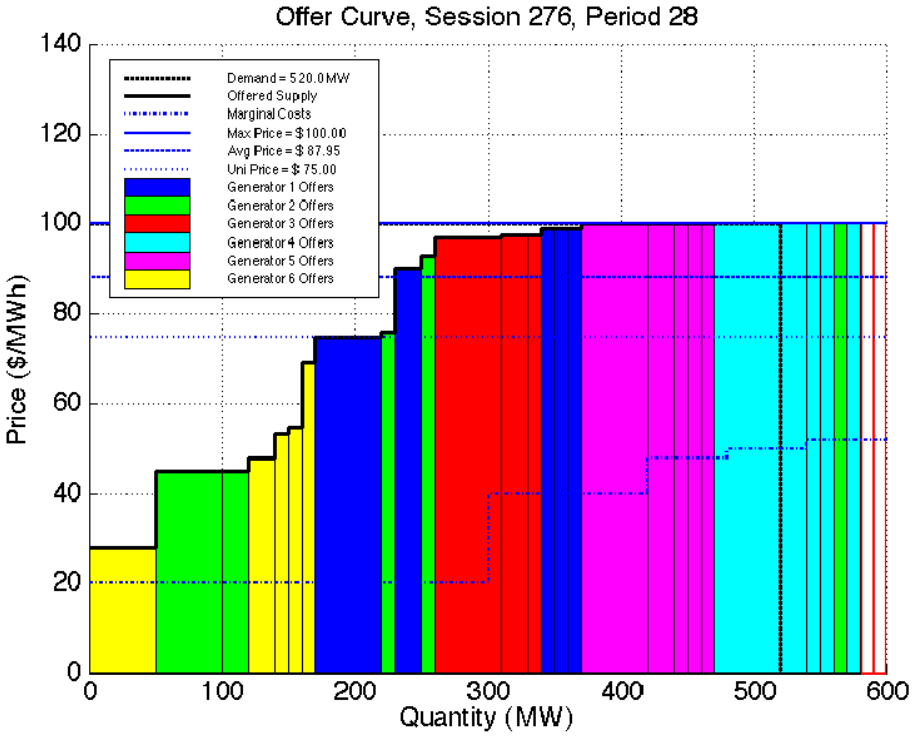


Figure 9: The actual offer curve 28 periods into the hybrid auction.

Table 1: Average prices and efficiencies for the three auctions

	Average Price	Efficiency
Uniform Price	$ 65.79	97.7%
Discriminatory	$ 68.54	95.3%
Hybrid	$ 78.89	95.7%

the discriminatory auction. We observe that price spikes do not always happen just during high load periods. We have noted that during the course of experimentation if there are market flaws that they are not always simple to find. As evidence, we ran several market power experiments and one in three groups of undergraduates with little or no market training could not exploit their position. On the other hand, experienced utility personnel or students trained in the electric markets always found the flaw.

Of special note is the fact that the information available to market participants is key to efficient market operation. For example, in the discriminatory auction, if high prices are paid for some blocks and these prices are hidden from the participants, then abuses are possible. Publishing an average price is not enough because participants will not know where the high average comes from, a single very high priced block or many lesser-priced blocks. It is uncertain whether publishing the highest price paid will provide those not getting the high price an incentive to offer their accepted units in at a higher price to try and capture a higher profit, or to offer their rejected units in at a lower price to undercut the high price unit.

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