ELECTRICITY SUPPLY CONTRACT AUCTIONS: KEY ISSUES AND EXPERIENCE
by
George Gross
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
Missouri University of Science and Technology,
April 20, 2009
© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
SCOPE OF THE PRESENTATION

- We study the design of electricity auctions for short- and mid-term supply contracts.
- The motivation comes from the drastic impacts of the 2006 Illinois Electricity Auction results.
- Our objectives are to identify the causes that produced such undesirable outcomes and to propose a solution to address the problems.
OUTLINE OF THE PRESENTATION

- The setting for the 2006 Illinois Electricity Auction

- Assessment of the principal design elements and their impacts on the Auction outcomes
  - auction format
  - product definition

- A proposal for improving the product definition for future auction design

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
BACKGROUND

- The volatility of electricity markets entails the need for effective financial tools such as forward contracts to manage the uncertainty impacts.
- One approach to select the suppliers for forward contracts is by using auction mechanisms.
- Auctions for short- and mid-term contracts have been implemented in Brazil, Chile and in several US states.
KEY ISSUES

- What and how to buy/sell are two natural questions that arise in the design of an auction.

Therefore, the essential auction design issues are

- the product definition; and

- the auction format and rules

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
MEETING THE LOAD DEMAND

MW

hour

$h_1$, $h_2$, $h_3$

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
MEETING DEMAND REQUIRES ALL 3 LAYERS OF THE SUPPLY CAKE
EVEN IF THERE ARE HOURS WHERE...
THE APPETITE IS FOR TWO LAYERS OF THE SUPPLY CAKE

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
OR IN SOME CASES WHERE...
THE APPETITE IS FOR ONLY A LAYER OF THE ELECTRICITY CAKE
ELECTRICITY SUPPLY AND FLOW

distribution company
- resource integration
- electricity delivery

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE AUCTION MECHANISM

- Auctions have been used for hundreds of years to buy and sell various products
- Auctions are useful when the willingness to sell is unknown
- Desirable characteristics of auctions are speed, transparency and non-discriminatory behavior
- The players are the sellers, the buyers and the auction manager
- Different auction types exist, including English, Dutch, sealed, pay as a bid and reverse
REVERSE AUCTION: EXAMPLE

- Objective: purchase 6 units of some product at the lowest possible price

- Four sellers, each with 2 units to sell

- Auction manager is an entity independent of each seller and the buyer
REVERSE AUCTION PARTICIPANTS

- single buyer
- auction manager
- seller A
- seller B
- seller C
- seller D

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
## SELLER COST DATA

<table>
<thead>
<tr>
<th>costs ($)</th>
<th>seller</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>$c_1$</td>
<td>6</td>
</tr>
<tr>
<td>$c_2$</td>
<td>10</td>
</tr>
</tbody>
</table>

$c_i = \text{costs of unit } i$

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE REVERSE AUCTION PROCESS

round price ($/unit)  round

20
15
13
11

number of units

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
## OUTCOME SUMMARY

<table>
<thead>
<tr>
<th>round</th>
<th>price ($/unit)</th>
<th>offer submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>2</td>
</tr>
</tbody>
</table>

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
STRATEGY ISSUES

- Timing of seller decision for reducing the quantity offer
- Public dissemination of information by the auction manager to all the sellers
- Avoidance of collusion among the sellers
The key objective of the Auction was to ensure reliable supply for the distribution companies of Ameren and Exelon.

NERA Economic Consulting designed, implemented and managed the auction.

The Auction used a reverse, simultaneous clock format.

The Auction was held from September 5 to 8, 2006.

Twenty one sellers participated in the Auction.
Ameren has three IL distribution companies: CILCO, CIPS and IP.

Ameren utilities serve 1,240,000 electric customers in central and southern Illinois.

Ameren Holding Company is a member of MISO.
EXELON

- ComEd is the distribution company of Exelon
- ComEd has more than 3.7 millions customers, serving about 70% of the state population
- Exelon is a member of PJM
ILLSINOIS RESTRUCTURING

- 1997: the *restructuring* of the Illinois electricity industry is enacted into law
- 1997 – 2007: the residential and small commercial tariffs are *frozen*; long-term contracts to meet Illinois utilities’ loads are signed
- 2006: *ICC approves* the auction proposed by the distribution entities of *Ameren* and *Exelon*
THE AUCTION CHARACTERISTICS

- The players: 2 buyers, 21 sellers and the Auction Manager
- The products: 8 different products
- The format was the reverse simultaneous clock auction
  - reverse: the sellers are the active players
  - simultaneous: all the products are traded together at the same time
  - clock: prices ‘tick-down’ in successive rounds
THE 2006 ILLINOIS ELECTRICITY AUCTION PLAYERS

ICC

Auction Manager

Auction Monitor

seller 1

seller 21

ComEd

Ameren
THE PRODUCT OF THE AUCTION ARE DIFFERENTIATED BY

- The distribution company:
  - Exelon’s ComEd; and
  - Ameren’s IP, CILCO and CIPS

- The customer class:
  - small and medium customers; and
  - large customers

- The contract duration:
  - 17 months; or,
  - 29 months; or,
  - 41 months
ILLINOIS ELECTRICITY AUCTION SET OF PRODUCTS

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE BASIC PRODUCT NOTION IN THE AUCTION

- Each *Auction* product is sold in *tranches*
- A *tranche* is defined as a specified fraction of the customer class load over the specified duration
- Each product has a given number of *tranches*
- For the set of 4 products for each distribution entity, a *load cap* is imposed to restrict the number of *tranches* that a single seller may sell

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE TRANCHE DEFINITION FOR A WEEKLY LOAD SHAPE
OVERVIEW OF THE AUCTION PROCESS

- The *Auction Manager* set **high initial prices** for each of the 8 products in the *Auction* in round 1.
- Each seller was allowed to offer **one or more tranches** of each of the 8 products.
- As long as there was an **oversupply** of any single product, a new round was launched by the *Auction Manager* with the prices in the new round modified from those in the previous round by non-negative decrements.

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
KEY AUCTION RULES

- A seller may not increase the total number of tranches from one round to the next, but may reallocate that number among the 8 products.
- The attainment of the supply – demand balance in all the products signals the completion of the Auction.
- Each seller of a specific product receives the identical price for each such product.

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
AUCTION INFORMATION FLOW

Auction Manager sets the round prices for each product

- Seller 1 provides number of tranches for each product
- Seller i provides number of tranches for each product
- Seller 2 provides number of tranches for each product

$\$/MWh $\$/MWh $\$/MWh

number of tranches number of tranches number of tranches

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
TRANCHE – BASED PRODUCT CHARACTERISTICS

- Uncertainty: the power and energy associated with each tranche of each product are uncertain.

- Artificiality: each tranche-based product is not a product efficiently produceable by any single generator but, typically, by a group of generators.

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
TRANCHE – BASED PRODUCT UNCERTAINTY

- Each product is inherently uncertain due to the random nature of the load, and uncertainty in the forecast.
- Each seller has a volumetric and a capacity uncertainty in its sales, where,
  - the volumetric uncertainty implies that the revenues of each seller are uncertain.
  - the capacity uncertainty implies that the utilization of the required resources is uncertain.
TRANCHE – BASED PRODUCT UNCERTAINTY

historical load

actual load

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
The tranche – based product may be efficiently produced only by a set of different generators for base, cycling and peak-load applications; its provision requires a seller to, in effect, become an aggregator of the outputs of different generators. As such, each seller of a product becomes a mini distribution company serving a scaled replica of the buying entity’s load for a particular customer class.
MINI ELECTRICITY – GENERATION – CAKES

distribution company:
delivery only entity

seller 1 . . . seller k . . . seller N

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE AUCTION FORMAT IMPACT ON SELLERS

- Allows the creation of portfolios to spread the uncertainty
- The rule of submitting offers with different allocations among the 8 products allows sellers to formulate appropriate strategies to handle uncertainties
- The rule of iterative decrements in the unit prices in each round provides information to tune the strategy of each seller

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE AUCTION FORMAT IMPACT ON BUYERS

- The load caps and the rule that prohibits any single seller from bidding above the load cap, avoid over dependence on a small number of sellers.

- The size of the *tranche* of each product – less than 50 MW – may allow the entry of small and medium size generating units and, thereby, stimulate more competition.
UNCERTAINTY IN THE AUCTION

- The product definition in the Auction impacts the type and level of uncertainty faced by the sellers and the buyers.
- The use of a tranche introduces considerable uncertainty for the sellers and virtually relieves the buyers from any uncertainty.
SELLER UNCERTAINTY

- Each seller is faced with the typical sources of uncertainty faced by generation entities such as fuel prices, forced outages and market prices.
- Due to the capacity and the volumetric uncertainty, each seller faces additionally the uncertainty, which was historically borne by the distribution companies.
LOAD UNCERTAINTY IS FACED ENTIRELY BY THE SELLERS
IMPACTS OF SELLER UNCERTAINTY

- A seller responds to the many sources of uncertainty by charging sufficiently high prices to ensure its ability to cover all its costs no matter what the actual load will be.

- Since, typically, a seller cannot efficiently produce the tranche-based product, he needs to purchase from the market and is exposed to its volatility or, alternatively, to sign side contracts which have their own sources of uncertainty.
ECONOMIC IMPACTS OF TRANCHE-BASED PRODUCTS

- The *tranche* contracts provide **full** protection to the *distribution* companies, by transferring all the uncertainty to the sellers; however, from the consumer’s viewpoint, this level of protection is beyond what consumers are willing to pay.

- The **uncertainty** associated with the migration of distributors’ consumers has a component of **information asymmetry** that likely will drive prices up.

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
ECONOMIC IMPACTS OF TRANCHE-BASED PRODUCTS

- The inability to meet of such contracts provides the impetus for consolidation of generation assets leading to the concentration of the market into fewer entities; such moves raise market power concerns and result eventually in reduced levels of competition.
ECONOMIC IMPACTS OF TRANCHE-BASED PRODUCTS

- The product definition does not allow revelation of the private demand forecast of each seller.

- As each seller must provide a specified fraction of the unknown demand, the information aggregation function of the market is undermined.
THE \textit{AUCTION} RESULTS: ROUND PRICE DYNAMICS

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{auction_results.png}
\caption{Auction Results: Round Price Dynamics}
\end{figure}

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
THE AUCTION RESULTS: SUCCESSFUL SELLERS
THE *AUCTION* RESULTS: PRICES

<table>
<thead>
<tr>
<th>customer class</th>
<th>small and medium</th>
<th>large</th>
</tr>
</thead>
<tbody>
<tr>
<td>buyer</td>
<td>ComEd</td>
<td>Ameren</td>
</tr>
<tr>
<td>product</td>
<td>CPP-B17</td>
<td>CPP-B29</td>
</tr>
<tr>
<td>initial price ($/MWh)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>final price ($/MWh)</td>
<td>63.96</td>
<td>64.00</td>
</tr>
</tbody>
</table>

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
2007 ILLINOIS HUB PRICES

$/MWh

BGS-LFP17  BGS-FP17  BGS-FP29  BGS-FP41

Jan 1      day      Dec 31

average LMP    daily LMP

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
2007 MISO PRICE DURATION CURVE

$/MWh

percent of time in the period

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
2007 CHICAGO HUB PRICES

$/MWh

CPP-A17  CPP-B17  CPP-B29  CPP-B41

average LMP  daily LMP

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
2007 PJM PRICE DURATION CURVE

$/MWh

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
TOWARD A MORE APPROPRIATE PRODUCT DEFINITION

- We propose to formulate the sales of each product in an auction in terms of fixed blocks of capacity and energy, which are closely related to the load shape of the product.

- For a particular load shape and for a specified period we define two $MW$ threshold levels:
  - $l_b$: minimum hourly load value of the period
  - $l_p$: minimum value of the peaking load

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
TOWARD A MORE APPROPRIATE PRODUCT DEFINITION

- These two load levels specify the three load segments: base, cycling and peaking.
- For each segment we define fixed MW blocks in terms of a specified duration and capacity.
IMPACTS OF THE BLOCK–BASED PRODUCTS

- Sellers continue to have the generating unit uncertainty but both the *volume* and the *capacity* are fixed for the period.

- Buyers *face* the *volumetric* and *capacity* uncertainty as the auction acquisition is for a pre–specified number of blocks.

- Each seller offers *natural* rather than the artificial *tranche*-based products.
BUYERS FACE LOAD UNCERTAINTY

The diagram illustrates the relationship between actual load, $l_p$, and the demand shape in the auction, $l_b$. It shows how buyers face load uncertainty in the context of MW demand over time (hour).

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
IMPLEMENTATION ISSUES

- Fine-tuning of the parameters, such as the threshold level load and the duration and capacity of each block
- Integration of renewable energy sources
- The use of sequential or simultaneous auctions
- Creation of an appropriate framework of rules appropriate for the block – based products and the auction format selected
- Design of contracts with clear specification of rights and obligations for sellers and buyers

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
CONCLUDING REMARKS

- The principal 2006 Illinois Electricity Auction design flaw was not the auction mechanism or format but the use of the tranche product definition.

- The tranche-based products cannot capture the salient characteristics of electricity.
CONCLUDING REMARKS

- Each seller is forced to become a *small distribution* entity.

- The large and varied sources of *uncertainty* faced by the sellers, the *artificiality* of the products and the *inefficient* dispatch result in prices much above the average *LMPs* in the electricity markets.
CONCLUDING REMARKS

- The block-based product definition can **overcome** the deficiencies of the *tranche*-based product definition by using a more **natural** product in line with the way in which electricity is generated.

- Future work includes: **auction design** for block-based product, **strategy** bidding issues, and
REFERENCES


© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
REFERENCES

- L. de Castro, M. Negrete-Pincetic and G. Gross,


  August-September 2008.
REFERENCES


© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
MULTIPLE – PRODUCT AUCTIONS

- The sale of multiple products may be done using sequential independent auctions, one for each product, or a simultaneous auction for all the products.

- A simultaneous auction may be performed using the reverse simultaneous ‘clock’ auction in which the prices ‘tick’ down throughout the process.
EXAMPLE OF TWO–PRODUCT REVERSE AUCTION

- Objective: purchase six units of product 1 and four units of product 2 at the lowest cost
- Players: four bidders, each with two units to sell of each product
- Rule: bidders can bid at most three units in any round
- Auction manager: updates both prices in each round
## SELLER COST DATA

<table>
<thead>
<tr>
<th>Costs ($)</th>
<th>Seller</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1^1$</td>
<td></td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>$C_2^1$</td>
<td></td>
<td>10</td>
<td>18</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>$C_1^2$</td>
<td></td>
<td>8</td>
<td>15</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>$C_2^2$</td>
<td></td>
<td>16</td>
<td>21</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

$C_i^j = \text{costs of unit } i \text{ of product } j$
MULTIPLE – PRODUCT REVERSE AUCTION PROCESS

product 1

price ($/unit)

20
15
15
15

units

product 2

price ($/unit)

20
17
16
14

units

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.
## OUTCOME SUMMARY

<table>
<thead>
<tr>
<th>round</th>
<th>prices</th>
<th>offer submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>product 1</strong></td>
<td><strong>product 2</strong></td>
</tr>
<tr>
<td></td>
<td>($/unit)</td>
<td>($/unit)</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>
## OUTCOME ANALYSIS

<table>
<thead>
<tr>
<th>Metric</th>
<th>Seller A</th>
<th>Seller B</th>
<th>Seller C</th>
<th>Seller D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>(2,1)</td>
<td>(1,0)</td>
<td>(1,2)</td>
<td>(2,1)</td>
</tr>
<tr>
<td>Revenues ($)</td>
<td>44</td>
<td>15</td>
<td>43</td>
<td>44</td>
</tr>
<tr>
<td>Costs ($)</td>
<td>24</td>
<td>3</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Profits ($)</td>
<td>20</td>
<td>12</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>

© 2009 University of Illinois at Urbana-Champaign, All Rights Reserved.