Price Discovery Algorithms across different contracts at IEX

(In compliance of Regulation 31(8) of Central Electricity Regulatory Commission (Power Market) Regulations, 2021)

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1. Background

1.1. Regulation 31(8) of Central Electricity Regulatory Commission (Power Market Regulations) 2021 has prescribed Power Exchanges to create and maintain a document on their website providing detailed description of the algorithm used for price discovery for all type of contracts. Accordingly, this document has been prepared and uploaded on the IEX website to disseminate details with respect to price discovery algorithms employed in different contracts.

1.2. The different contracts presently being offered at IEX platform along with their price discovery methodology is summarized in the Table below:

Table 1: Price Discovery Methodology across different contracts at IEX

Market Segment	Contract	Price Discovery Methodology
Integrated Day Ahead Market (IDAM)	Day Ahead Market (DAM)	Double sided closed bid uniform price auction
	Green Day Ahead Market (GDAM)	
	High Price Day Ahead Market (HPDAM)	
Real Time Market (RTM)	Real Time Market Contract	Double sided closed bid uniform price auction
Intraday & Contingency Market, Green ITD & Contingency Market and High price ITD & Contingency Market	Day Ahead Contingency Contract	Continuous matching
	Intra-Day Contract	
Term Ahead Market (TAM), Green Term Ahead Market (GTAM) & High price Term Ahead Market (HPTAM)	Daily Contract	Double-sided open bid uniform price step auction
	Weekly Contracts	
	Monthly Contracts	
	Any Day Single Sided Contracts	Reverse Auction
Renewable Energy Certificates (REC) Market	Renewable Energy Certificates (REC) Contract	Double-sided close bid uniform price step auction
Energy Savings Certificate (Escert) Market	Energy Savings Certificate (Escert) Contract	Double-sided close bid uniform price step auction

1.3. Based on the above Table, the price discovery methodology followed by the Exchange can be classified into following broad categories:

a) Double sided close bid uniform price auction
b) Continuous Matching
c) Double-sided open/ close bid uniform price step auction
d) Reverse Auction

The algorithms of above methodologies have been discussed in detail in the subsequent sections.

2. Double sided close bid uniform price auction:

2.1. The double-sided closed bid uniform price auction mechanism is administered for price discovery in the IDAM and RTM segments which are based on principles of collective transactions. The buyers and sellers submit their bids during the market hours based on which the market clearing engine discovers the Market Clearing Price (MCP) and Market Clearing Volume (MCV) upon closure of the market. The details of the bid types and algorithm used for the price discovery are discussed in the sections below.

2.2. **Bid Types:** The different bid types available for trading in IDAM and RTM segment are as follows:

2.2.1. **Single Bid:** Single bid allows the market participants to specify multiple sequences of price and quantity pairs in a portfolio manner. The quantity shall be assumed to vary linearly between two price pairs. This bid type is available in IDAM & RTM segment.

2.2.2. **Block Bid:** Block bid allows the market participants to specify one price and one quantity for a combination of continuous 15-minute time blocks. Selection criterion shall be average of Area Clearing Price (ACP) for the quoted 15-minute time blocks of the respective client's bid area. It will be an 'All or None' type of order. This bid type is available in IDAM & RTM segment.

2.2.3. **Minimum Quantity Block Bid:** Minimum Quantity Block Bids allows the market participants to specify one price and one quantity for a combination of continuous 15-minute time blocks along with a 'Minimum Quantity percentage' and number of sub-bids. The minimum quantity percentage will specify the quantity up to which the block bid can be accepted whereas the number of sub-bids will specify] the size in which the remaining quantity shall be divided into. This bid type is available in IDAM segment.

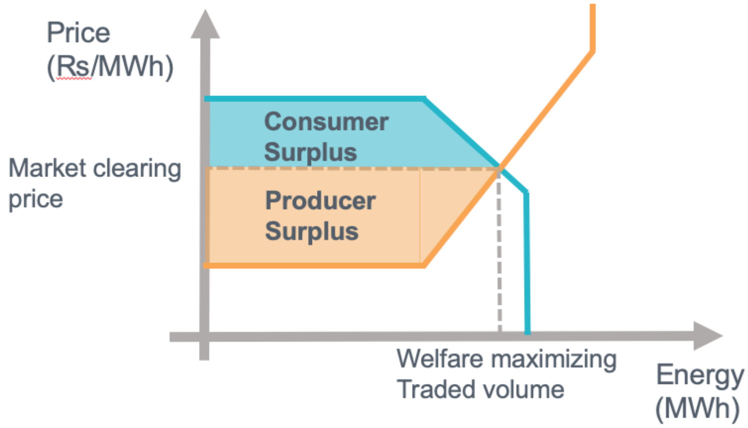
2.2.4. **Profile Block Bid:** Profile Block bid allows the market participants to specify one price and varying quantities for a combination of continuous 15-minute time blocks. Selection criterion shall be based on weighted average of ACP for the quoted 15-minute time blocks of the respective client's bid area. It will be an 'All or None' type of order. This bid type is available in IDAM segment.

2.2.5. **Linked Bid:** In the linked bid two different block bids can be linked as parent and child bid. The child bid is considered for selection only when the parent bid is selected. Both the bids will be selected if the combined value obtained from parent and child bid is found to be positive.

2.3. **Algorithm for Price Discovery:** The algorithm used in IDAM and RTM for price discovery is based on Mixed Integer Programming (MIP). The algorithm aims to maximize the social welfare i.e., maximize the sum of consumer and producer surplus in the market within the bid and network constraints and solves the problem based on Branch & Bound (B&B) technique. The principles based on which the algorithm is modeled are described below:

2.3.1. **Purpose of the model:** The purpose of the algorithm is to maximize social welfare in a uniform pricing close bid auction market. Economically, the social welfare in a market is the sum of the consumer surplus with producer surplus. The graphic representation of these concept is given on Figure 1, with the volume of energy traded on the X-axis and the price per unit on the Y-axis. The producer price per unit function is given in dark orange, while the willingness to pay per unit is shown in dark blue.

Figure 1 - Representation of Consumer and Producer Surplus and Social Welfare.



Main Steps of the Algorithm: An overview of each step of the computations has been described below:

i. **Step 1: MIP solving by B&B Technique -** The first step consists of searching for integer feasible solutions to an optimization problem which maximizes the social welfare of markets participants while ensuring that the network constraints are satisfied. The problem is solved using the B&B algorithm. The B&B algorithm will produce one or several candidate integer feasible solutions which must be checked for existence of feasible prices in the following step.

ii. **Step 2: Dual feasibility -** When a candidate integer feasible solution is reported by the B&B, it is checked that corresponding feasible market prices exist using the equivalence between welfare maximization and aggregated curves intersection. This amounts to solving a modified version of the dual problem of the MIP relaxation (a modified dual is solved as some additional constraints formalizing the acceptance conditions of the block bids are added to the dual, which is thus an augmented dual). If no feasible market prices are found, the algorithm returns to step 1, looking for other candidate integer feasible solutions. Otherwise, it moves to step 3.

iii. **Step 3: Post-Processing's -** Step 3 applies the various post-processing's (volume maximization, flow costs minimization, tie-breaking for equivalent-but-price or equivalent-but-timestamp block bids) to the integer solution with feasible market prices found at the end of step 2.

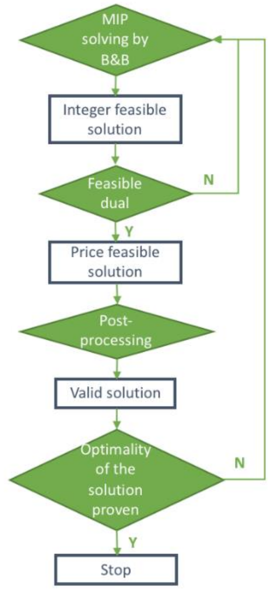
iv. **Step 4: Optimality proven -** When step 3 is finished, a fully valid solution is obtained. However, there might remain many combinations of orders selection/acceptances not explored yet by the B&B algorithm. Therefore, there might exist other solutions with higher welfare. The B&B algorithm provides information on that and helps to assess if the new valid solution can be proven to be the best one.

   - If the new valid solution can be proven optimal or
   - If the computation time given to the algorithm is exceeded,

   Then the algorithm stops. Otherwise, the algorithm goes back to step 1 and looks for other welfare improving integer feasible solutions to the MIP.

The main steps of the computations performed by the Matching Solution are represented on Figure 2.

Figure 2 - Main steps of the Power Matching Solution.

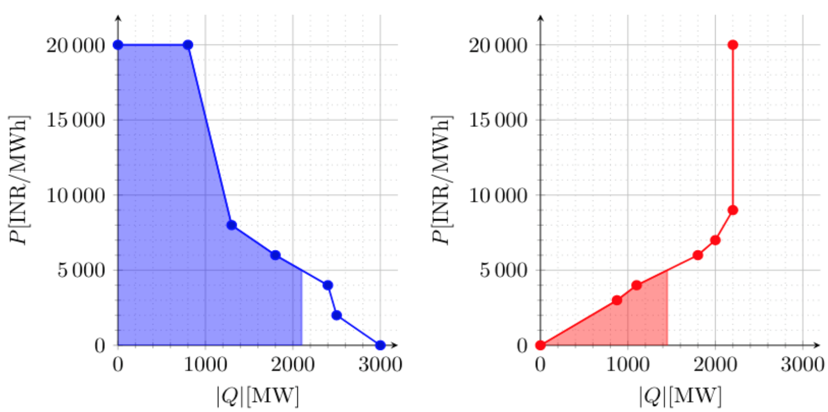


2.3.2. Optimization Approach: The optimization approach has been further explained in the following paragraphs:

i. **MIP welfare maximization by B&B Technique (Primal Problem).** The first step of the algorithm is to search for integer feasible solutions to the welfare maximization problem (or primal problem). Those solutions are feasible combinations of bid's acceptances such that the power balance and network constraints are satisfied.

   - **Social Welfare Maximization:** The social welfare is a measure of the total value generated by a (set) of trade(s) for the society. The welfare is equal to the sum of the valuation of the matched demand bids minus the sum of the costs of the matched supply bids (i.e., the value created for the society minus the cost incurred by the society). The welfare expression is thus a simple expression that provides the area below demand bids minus the area below supply bids given the quantity accepted in each of the bids. As the algorithm searches for the solution with maximum welfare, the respective contribution of the bids to the social welfare determines whether they will be accepted with higher priority by the welfare maximization problem. Figure 3 shows a graphical representation of the contribution to the welfare for a demand single bid and a supply single bid.

Figure 3 - Social welfare of a single demand and a supply single bid



- **Bid Specific Constraints:** Each bid (single bid or block bid) brings a contribution to the social welfare which is obtained by computing the area below the bid price curve as explained in the previous subsection. The welfare maximization problem is a Mixed Integer Problem because the block bids require to resort to binary variables (variables that can be 0 or 1 but can't take any value in between) due to their fill or kill nature.
- **Network Specific Constraints:** The network model used by the welfare maximization problem is a simple flow network with maximum capacities on the lines. The network is made of several bidding areas linked by lines. On each line, the maximum power flow is required to be below a capacity provided by the network operator (the capacity can be different for the upward direction of the line and the downward direction of the line).
- **Solving using B&B Technique:** The welfare maximization problem is a Mixed Integer Problem (MIP), i.e., an optimization problem involving both continuous and integer variables. In practice, all integer variables are binary variables (i.e., variables which should take the value 0 or 1) modelling the acceptance of block bids. The MIP is solved using the Branch & Bound algorithm. B&B algorithm search for the combination of block bids acceptances, single bids acceptance levels and flows leading to the highest welfare value. In other words, it will compute the welfare reached for every feasible selection of bids until it finds the best one. As there are many feasible combinations of bid's selections while the algorithm is only given a limited amount of time, it can be that the Branch & Bound process doesn't have time to enumerate all the possible combinations. In such a case, it returns the combination with the highest welfare found so far. For transparency, the algorithm also informs the user whether the solution returned was proven to be optimal or if some feasible combinations remained unexplored and by how much (welfare) they might potentially outperform the returned solution.

ii. Dual Feasibility (Dual Problem): The dual feasibility check aims at computing feasible market prices given an integer feasible (non-necessarily optimal) solution to the welfare maximization problem reported by the Branch & Bound algorithm. The dual feasibility check amounts to solving an optimization problem too as some indeterminacies on the price (where there exists more than one market clearing price with same social welfare) will have to be lifted. Each constraint of the primal problem corresponds to a variable of the dual problem and conversely, each variable of the primal corresponds to the dual problem. The constraints and objective function used in the dual problem is described below:

- **Objective of the Dual Problem:** The dual feasibility check is a minimization problem. It aims at minimizing the distance of the market price to the midpoint of the interval of the feasible prices
- **Constraints coming from the Bids:** The level of acceptance of each bid in the integer feasible solution implies some constraints on the market prices.
  - For single bids, a single bid should neither be (partially or fully) paradoxically rejected, nor (partially or fully) paradoxically accepted.
  - For block bids, a block bid should not be (partially or fully) paradoxically accepted.
- **Constraints coming from the network:** The flow values of the integer feasible solution imply some constraints on the market prices. Let us assume bidding areas 1 and 2 are linked by a line. Then, the price in bidding area 2 can be strictly bigger than the price in bidding area 1 if and only if the flow from bidding area 1 to bidding area 2 is at the maximum value authorized by the capacity constraint in that direction. Similarly, the price in bidding area 1 can be strictly bigger than the price in bidding area 2 if and only if the flow from bidding area 2 to bidding area 1 is at the maximum value authorized by the capacity constraint in that direction. In other words, two linked bidding area always have equal prices when there is no congestion on the line between them.

iii. **Post-processing's:** The post processing's are Volume maximization, Minimization of flows costs and Tie-breaking for block bids. Each of those post processing's steps might change the solution but not the corresponding welfare value.

2.3.3. **Step-by-step application of the algorithm on Examples:** In this section, the steps of the algorithm as described above has been applied over select examples.

2.4.1.1. **An example without network**

Let's assume there is a single bidding area and no network. The following table defines three bids /belonging to the bidding area.

		Single bids			
		Point 1	Point 2	Point 3	Point 4
Buy bid 1	Quantity [MW]	0	0	20	20
	Price[INR/MWh]	20000	6001	6000	0
Sell bid 2	Quantity [MW]	0	0	60	60
	Price[INR/MWh]	0	3000	3001	20000

		Block bids
Buy bid 3	Quantity [MW]	60
	Price[INR/MWh]	5000

Branch & Bound on the welfare maximization problem

The first step of the algorithm is to create the welfare maximization problem and to search for candidate integer feasible solutions using the B&B algorithm. Given the above bid orders, the welfare maximization MIP is the following:

$$\max_{x,u,e} 20\, x_{1,1}\left(6001 - \frac{x_{1,1}}{2}\right) - 60\, x_{2,1}\left(3000 + \frac{x_{2,1}}{2}\right) + \ 300000\, x_3$$

$$0 \leq x_{1,1} \leq 1$$
$$0 \leq x_{2,1} \leq 1$$
$$0 \leq x_3 \leq u_3$$
$$u_3 \leq x_3$$
$$e_{1,1} = -20\, x_{1,1} + 60\, x_{2,1} - 60\, x_3$$
$$e_{1,1} = 0$$
$$u_3 \in \{0,1\}$$

The B&B applied to the welfare maximization problem will report two incumbent solutions, one rejecting the block bid and one accepting the block bid. The two candidate's integer feasible solutions are thus as follows:

- Candidate solution 1: Welfare is 60006.666…
  - Accept 20 MW in the buy single bid 1
  - Accept 20 MW in the sell single bid 2
  - Reject the buy block bid 3
- Candidate solution 2: Welfare is 119970
  - Reject the buy single bid 1
  - Accept 60 MW in the sell single bid 2
  - Accept 60 MW in the buy block bid 3

As candidate solution 2 reaches a higher welfare, it will be preferred by the algorithm if there exist corresponding feasible prices. For each of the candidate solutions, the algorithm will look for corresponding feasible markets prices (also referred to as a corresponding feasible dual solution). If such prices exist for candidate solution 2, it will be the final solution.

Computing market prices and applying the midpoint rule

For candidate solution 1, the acceptances of the bids imply the following constraints

- The market price should be below 6000 INR/MWh (buy single bid 2 is accepted)
- The market price should be above 3000.33 INR/MWh (sell single bid 1 is partially accepted)

This leaves an indeterminacy on the price. The indeterminacy is lifted by the midpoint rule which incentivizes the algorithm to pick the price as close as possible to the midpoint of the interval of feasible prices (the interval is thus [3000.33…; 6000]). The price problem minimizing the mid-point rule is written below. The optimal price turns out to be 4500.166… INR/MWh.

$$\min_{\varphi_{1,1}} \left(\varphi_{1,1} - \frac{27001}{6}\right)^2$$

$$\frac{9001}{3} \leq \varphi_{1,1} \leq 6000$$

For candidate solution 2, the acceptances of the bids imply the following constraints

- The market price should be above 6001 INR/MWh (buy single bid 1 is rejected)
- The market price should be above 3001 INR/MWh (sell single bid 2 is accepted)
- The market price should be below 5000 INR/MWh (buy block bid 3 is accepted)

Which is clearly infeasible. Therefore, there exist no valid prices for candidate solution 2 and it must be rejected. The algorithm then fallbacks on candidate solution 1.

Post-processing's

For candidate solution 1, there is no remaining indeterminacy on the matched volume and flows on lines. Tie-breaking for block orders is also not needed.

2.4.1.2. **An example with network**

Let us assume we have a network made of two bidding areas linked by a line with a capacity of 150 MW from bidding are 1 to bidding area 2 and 0 MW from bidding area 2 to bidding area 1. The bids in bidding areas 1 and 2 are as described in the tables below:

		Single Bids			
		Point 1	Point 2	Point 3	Point 4
Buy bid 1	Quantity [MW]	0	0	330	330
	Price [INR/MWh]	20000	4001	4000	0
Sell bid 2	Quantity [MW]	0	0	500	500
	Price [INR/MWh]	0	2000	2001	20000

Bids of bidding area 1

		Single bids			
		Point 1	Point 2	Point 3	Point 4
Buy bid 3	Quantity [MW]	0	0	120	120
	Price[INR/MWh]	20000	4001	4000	0

		Block bids
Buy bid 4	Quantity [MW]	50
	Price[INR/MWh]	3000

Branch & Bound on the welfare maximization problem

The first step of the algorithm is to create the welfare maximization problem and to search for candidate integer feasible solutions using the B&B algorithm. Given the above bid orders the welfare maximization MIP is the following:

$$\max_{x,u,e,f} 330\, x_{1,1}\left(4001-\frac{x_{1,1}}{2}\right)-500\, x_{2,1}\left(2000+\frac{x_{2,1}}{2}\right)+120\, x_{3,1}\left(4001-\frac{x_{3,1}}{2}\right) + 150000\, x_4$$

$$0 \le x_{1,1} \le 1$$
$$0 \le x_{2,1} \le 1$$
$$0 \le x_{3,1} \le 1$$
$$0 \le x_4 \le u_4$$
$$u_4 \le x_4$$
$$e_{1,1} = -330\, x_{1,1} + 500\, x_{2,1}$$
$$e_{2,1} = -120\, x_{3,1} - 50\, x_4$$
$$e_{1,1} = f_1^+ - f_1^-$$
$$e_{2,1} = -f_1^+ + f_1^-$$
$$0 \le f_1^+ \le 150$$
$$0 \le f_1^- \le 0$$
$$u_4 \in \{0,1\}$$

The B&B applied to the welfare maximization problem will report two incumbent solutions, one rejecting the block bid and one accepting the block bid. The two candidate's integer feasible solutions are thus as follows:

- Candidate solution 1: Welfare is 900022.5
  - Accept 330 MW in the buy single bid 1
  - Accept 450 MW in the sell single bid 2
  - Accept 120 MW in the buy single bid 3
  - Reject the buy block bid 4
  - 120 MW flows from bidding area 1 to bidding area 2
- Candidate solution 2: Welfare is 909992.93…
  - Accept 330 MW in the buy single bid 1
  - Accept 480 MW in the sell single bid 2
  - Accept 100 MW in the buy single bid 3
  - Accept 50 MW in the block bid 4
  - 150 MW flows from bidding area 1 to bidding area 2

As candidate solution 2 reaches a higher welfare, it will be preferred by the algorithm if there exist corresponding feasible prices. For each of the candidate solutions, the algorithm will look for corresponding feasible markets prices (also referred to as a corresponding feasible dual solution). If such prices exist for candidate solution 2, it will be the final solution.

Computing market prices and applying the midpoint rule

For candidate solution 1, the acceptances of the bids and the flows imply the following constraints

- The market price in bidding area 1 should be below 4000 INR/MWh (buy single bid 1 is accepted)
- The market price in bidding area 1 should be at 2000.9 INR/MWh (sell single bid 2 is partially accepted)
- The market price in bidding area 2 should be below 4000 INR/MWh (buy single bid 3 is accepted)

- The market prices in bidding areas 1 and 2 must be equal as there is no congestion on the line (flow is 120 MW which is strictly smaller than 150 MW)

This leaves no indeterminacy on the market prices. Indeed, the prices problem minimizing the mid-point rule is as follows.

$$\min_{\varphi_{1,1}} \varphi_{1,1}^2 + \left(\varphi_{2,1} - \frac{4000}{2}\right)^2$$

$$\varphi_{1,1} = 2000.9$$
$$\varphi_{2,1} \leq 4000$$
$$\varphi_{1,1} = \varphi_{2,1}$$

The market price is thus 2000.9 INR/MWh in both bidding areas.

For candidate solution 2, the acceptances of the bids and the flows imply the following constraints

- The market price in bidding area 1 should be below 4000 INR/MWh (buy single bid 1 is accepted)
- The market price in bidding area 1 should be at 2000.96 INR/MWh (sell single bid 2 is partially accepted)
- The market price in bidding area 2 should be at 4000.833… INR/MWh (buy single bid 3 is partially accepted)
- The market price in bidding area 2 should be below 3000 INR/MWh (sell block bid 4 is accepted)

$$\min_{\varphi_{1,1}} \varphi_{1,1}^2 + \varphi_{2,1}^2$$

$$\varphi_{1,1} = 2000.96$$
$$\varphi_{2,1} = 4000.833$$
$$\varphi_{2,1} \leq 3000$$
$$\varphi_{1,1} \leq \varphi_{2,1}$$

Which is clearly infeasible. Therefore, there exist no valid prices for candidate solution 2 and it must be rejected. The algorithm then fallbacks on candidate solution 1.

Post-processing's

For candidate solution 1, there is no remaining indeterminacy on the matched volume and flows on lines. Tie-breaking for block orders is also not needed.

2.4. **Matching Rules:** The buy bids and sells bids are aggregated to form Aggregated Buy and Aggregated Sell curve and the intersection of the aggregated curve gives the Area Clearing Price (ACP) and Area Clearing Volume (ACV). The matching rules followed in price discovery are summarized below:

2.4.1. All buy bids to have non-increasing quantity and sell bids to have non-decreasing quantity for every increase in bid price; all buy and sell bids to be assumed to vary linearly between consecutive prices having a sloping curve.

2.4.2. All buy and sell bids are aggregated to tracing the Aggregated Buy and Aggregated Sell curves for every 15 minutes time block. The quantity provided under Block buy & sell bids to be added across the price ticks.

2.4.3. The intersection of Aggregated Buy and Aggregated Sell curves gives the MCP and MCV for that time block. In case there is a vertical overlapping curve the midpoint of the curve is considered as the ACP. In case the Aggregated Buy & Sell bids are not intersecting due to over-supply or over demand scenario then the curves are suitably shifted so that both the curves intersect to arrive at the ACP and ACV.

2.4.4. As the Block bids are indivisible bids the average price across time blocks is compared with the quoted price. A buy block bid is accepted if the average price computed is lower than the quoted price and a sell block bid is accepted if it is the other way around. In case selection is to be made out of more than one similarly placed block bids then bids will be selected based on time priority of bid submissions.

2.4.5. If there is no congestion in the network the Area Clearing Price become same as Market Clearing Price. In case there is a congestion the market is split into congested bid area & remaining areas and the price is computed separately and then the flow is allowed between the surplus and deficit areas to the extent of availability of transmission lines.

2.5. **Step-by-step application of the algorithm on Examples:** In this section, the steps of the algorithm as described above has been applied over select examples.

2.5.1. **An example with only Single Bids:** Let's assume the following bids to have been received in the system for the following time block and bid area:

Time: 00:00-00:15

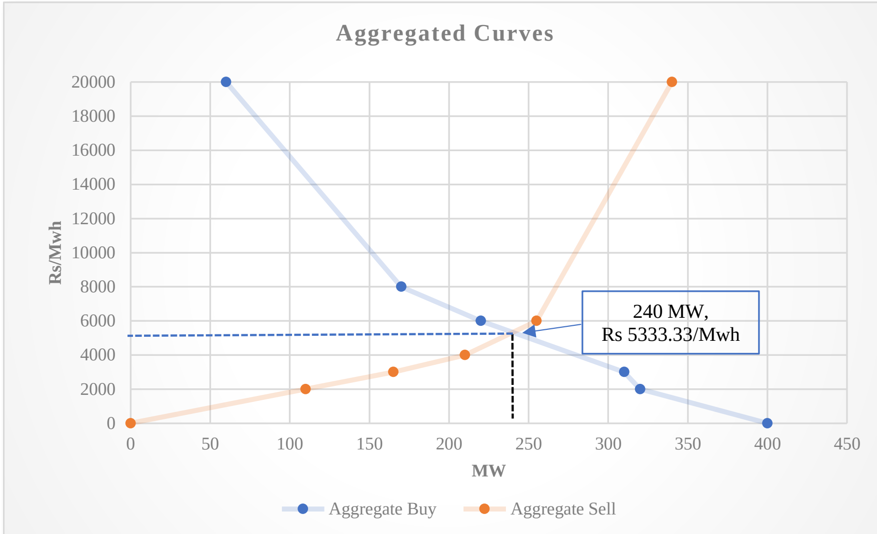
Bids	Price/Qty	P/Q 1	P/Q 2	P/Q2	P/Q3
Buy Bid 1	Price (Rs/Mwh)	0	3000	8000	20000
	Quantity (MW)	200	200	100	50
Buy Bid 2	Price (Rs/Mwh)	0	2000	6000	20000
	Quantity (MW)	200	120	80	10
Sell Bid 1	Price (Rs/Mwh)	0	2000	4000	20000
	Quantity (MW)	0	-50	-100	-140
Sell Bid 2	Price (Rs/Mwh)	0	3000	6000	20000
	Quantity (MW)	0	-90	-150	-200

Aggregation of Buy and Sell Bids:
The buy and sell bids are aggregated to form Aggregated Demand and Aggregated Supply bids as under:

Aggregated Bids	Price/Qty	P/Q 1	P/Q 2	P/Q 3	P/Q 4	P/Q 5	P/Q 6
Buy Bids	Price (Rs/Mwh)	0	2000	3000	6000	8000	20000
	Quantity (MW)	400	320	310	220	170	60
Sell Bids	Price (Rs/Mwh)	0	2000	3000	4000	6000	20000
	Quantity (MW)	0	-110	-165	-210	-255	-340

In the Buy and Sell Bids, the quantity at several price points is not quoted. Hence for aggregation of the Buy and Sell Bids, the quantity corresponding to such price points are being determined through straight line equation.

The Aggregated Buy & Sell curves are traced, and the intersection of the curves gives the solutions for the market i.e., Area Clearing Price (ACP) and Area Clearing Volume (ACV) as provided in the figure below.



In the present example these aggregated curves cut each other at Rs. 5333.33/Mwh and the cleared volume is 240 MW. Hence the volume corresponding to the price Rs. 5333.33/Mwh gets allocated to the respective Buy and Sell bids. In the present case, 153.33 MW shall be allocated to Buyer-1 and 86.67 MW to Buyer-2 whereas 103.33 MW will be allocated to Seller -1 and 136.67 MW to Seller -2.

2.5.2. **An example with Single and Block Bids:** Let's assume the following bids to have been received in the system for the following time blocks and bid area:

Time: 00:00-00:15

Bids	Price/Qty	P/Q 1	P/Q 2	P/Q2	P/Q3
Buy Bid 1	Price (Rs/Mwh)	0	4000	8000	20000
	Quantity (MW)	450	300	100	0
Sell Bid 1	Price (Rs/Mwh)	0	3000	6000	20000
	Quantity (MW)	0	100	300	500

Time: 00:15-00:30

Bids	Price/Qty	P/Q 1	P/Q 2	P/Q2	P/Q3
Buy Bid 2	Price (Rs/Mwh)	0	3000	5000	20000
	Quantity (MW)	400	300	100	0
Sell Bid 2	Price (Rs/Mwh)	0	2000	6000	20000
	Quantity (MW)	0	200	400	600

Time: 00:00-00:30

Block Bid	Price/Qty	P/Q 1
Buy Bid 3	Price (Rs/Mwh)	5000
	Quantity (MW)	100

Aggregation of Buy and Sell Bids:

The buy and sell bids are aggregated to form Aggregated Demand and Aggregated Supply bids across the two time block as given under:

Time: 00:00-00:15

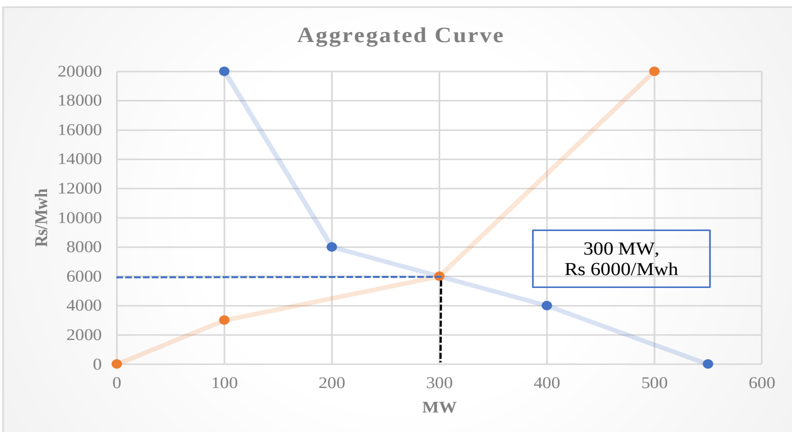
Aggregated Bids	Price/Qty	P/Q 1	P/Q 2	P/Q 3	P/Q 4
Buy Bids	Price (Rs/Mwh)	0	4000	8000	20000
	Quantity (MW)	550	400	200	100
Sell Bids	Price (Rs/Mwh)	0	3000	6000	20000
	Quantity (MW)	0	100	300	500

Time: 00:15-00:30

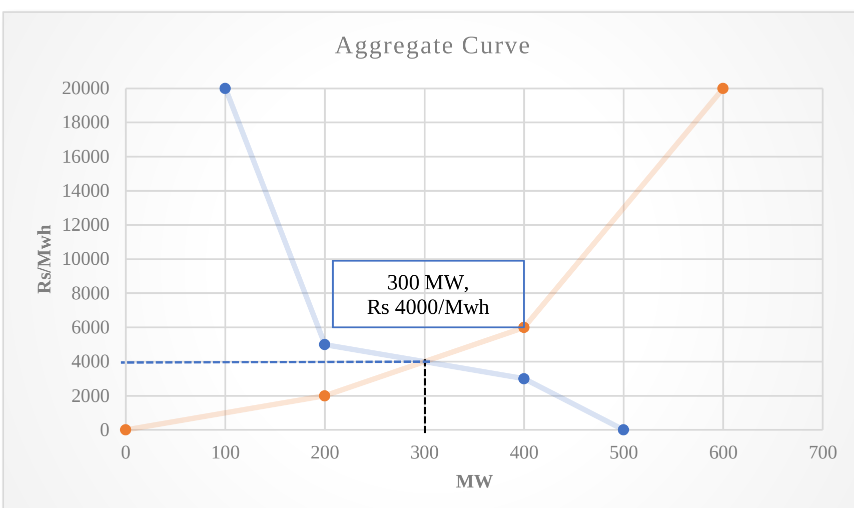
Aggregated Bids	Price/Qty	P/Q 1	P/Q 2	P/Q 3	P/Q 4
Buy Bids	Price (Rs/Mwh)	0	3000	5000	20000
	Quantity (MW)	500	400	200	100
Sell Bids	Price (Rs/Mwh)	0	2000	6000	20000
	Quantity (MW)	0	200	400	600

The quantity specified under the Buy Block bid i.e., 100 MW is aggregated in Buy Curve across the price ticks to arrive at the clearing price & volume as provided in the figure below:

Time: 00:00-00:15



Time: 00:15-00:30

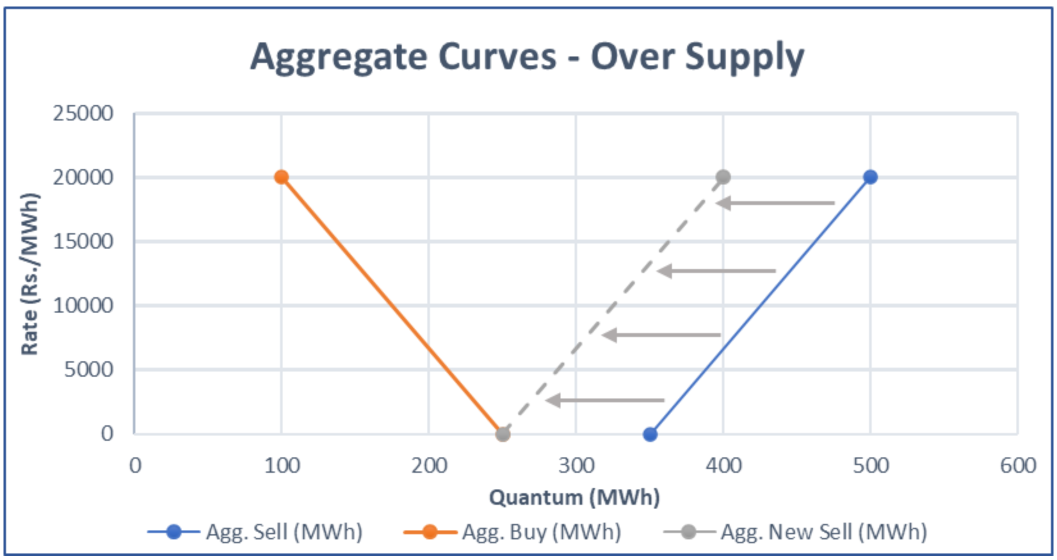


Selection of Block Bid:
The ACP discovered during time block 00:00-00:15 & 00:15-00:30 is observed to be Rs. 6000/Mwh and Rs. 4000/Mwh respectively. The block buy bid will get accepted as the average ACP is found to be Rs. 5000/Mwh.

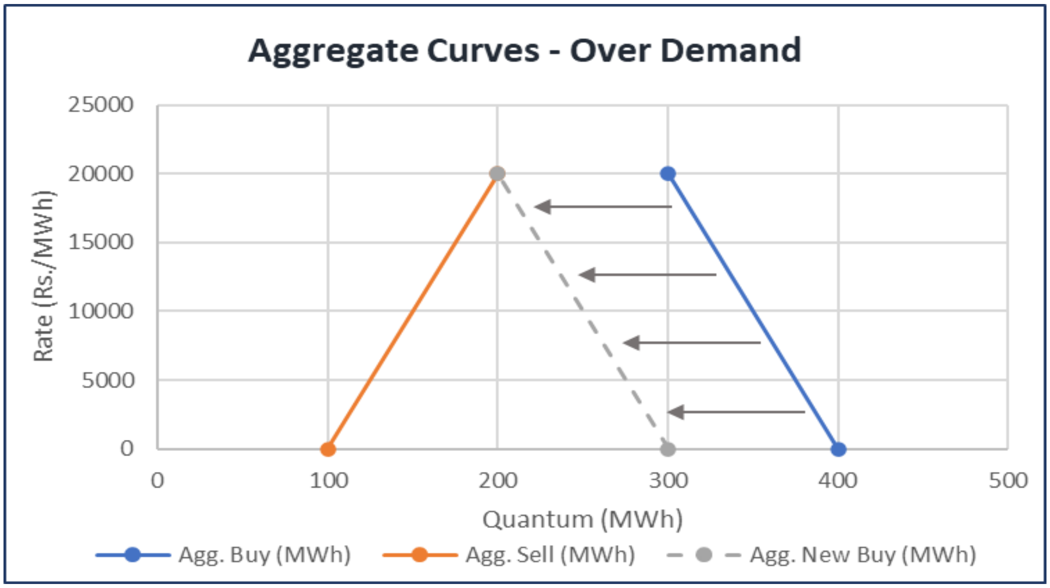
Accordingly, volume cleared across different buy and sell bids will be as follows: Buy Bid 1 – 200 MW; Sell Bid 1 – 300 MW; Buy Bid 2 – 200 MW; Sell Bid 2 – 300 MW; Buy Block Bid 3 – 100 MW.

2.5.3. **An example with the non-overlapping buy-sell curve:** If the buy and sell curves do not cross each other between the price range defined by the Exchange, then in case of oversupply, sell offers will be reduced proportionately so that curves cross each other at minimum price and in case of over demand, purchase bids will be reduced proportionately so that curves cross each other at maximum price.

In case of over-supply, as shown in figure below, where supply and demand curves does not intersect each other, the entire aggregated supply curve is shifted to the left so that both the curves intersect at the minimum. In the graph below, aggregate supply curve is shifted by 100MW to the left (from 350MW to 250MW at Rs0/MWh) so that both the curves now intersect at the minimum price point. Here the ACP would be Rs 0/MWh, being the point of intersection with modified supply curve. In such situation quantity is prorated amongst suppliers at minimum price. Therefore, in present case quantities quoted by all suppliers would be reduced by a factor of (250/350), and this revised quantity would be allocated to individual supplier.



In case of over-demand, the aggregated supply and demand curves are made to intersect at the maximum price point by shifting the demand curve to the left. In this case demand curve is shifted 100MW to the left so that now the curves intersect at the maximum price point, which is Rs 20000/MWh. The MCP in this case would be Rs. 20000/- and the quantity allocation amongst buyers at this price.



Pro rata allocation of quantum is done in such over-supply and over-demand cases. For example, take the case of over-demand as shown in the graph above. Consider that there are four sellers totaling 200 MW and two buyers totaling 300MW at Rs 20000/MWh; buyer-1 and buyer-2 contributing 100 MW and 200 MW respectively. All sellers would be selected whereas buyer-1 will get (100*200/300) MW and buyer-2 will get (200*200/300) MW. Similar prorate allocation shall be done to sellers, in case of over-supply.

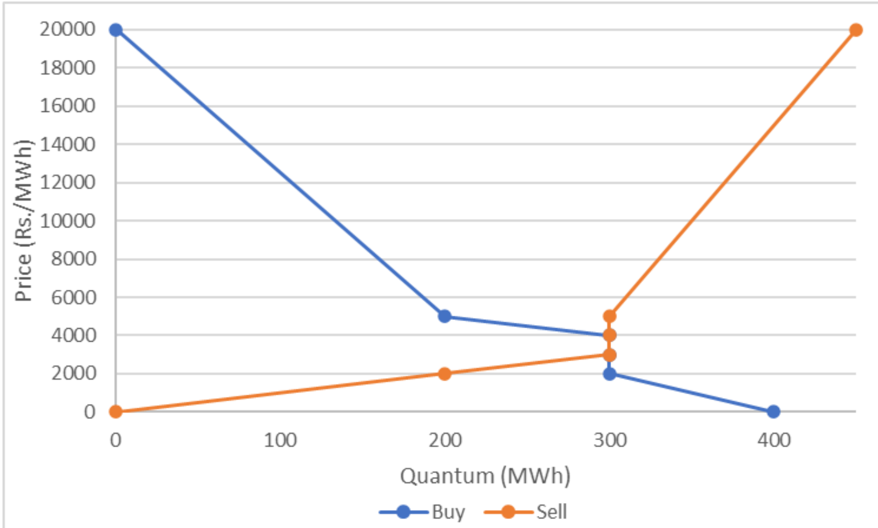
2.5.4. **An example of vertically intersecting Buy-Sell curves:** In cases of vertical overlap, midpoint of the overlapped section shall be considered as the ACP; however, in case overlap starts right at the minimum price 'zero' has been set by the Exchange as minimum price minimum price (Zero) shall be considered as ACP. For example, consider the following aggregate Buy and sale bids.

Aggregate Buy bid:

Price (Rs/MWh)	0	2000	4000	5000	20000
Quantity (MWh)	400	300	300	200	0

Aggregate Sell bid:

Price(Rs/MWh)	0	2000	3000	5000	20000
Quantity(MWh)	0	200	300	300	450



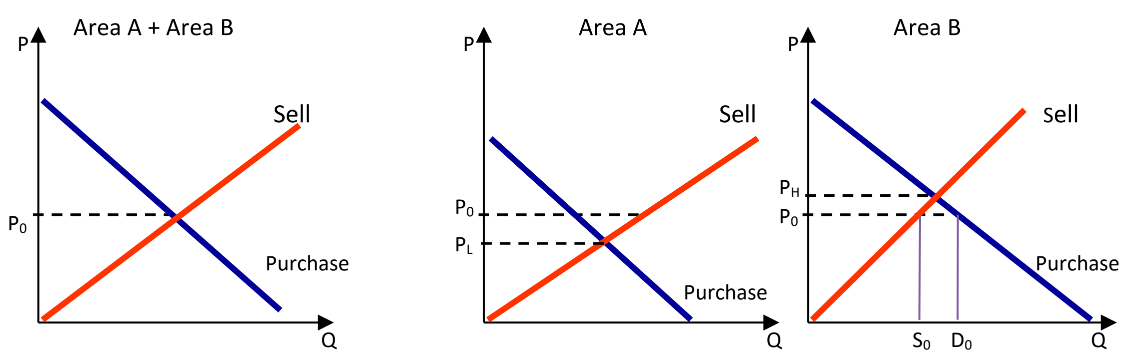
In the above case, the aggregate buy and sell curves overlap between the price range Rs 4000/MWh and Rs 3000/MWh. Midpoint of the overlap shall be considered as ACP, which is **Rs 3500/MWh.**

2.6. **Market Splitting:** In case of transmission congestion a solution is to be worked out on the basis of market splitting. Market splitting is an evolved form of implicit auctioning wherein energy component and corresponding transmission capacity between bid areas are traded simultaneously. In the market splitting methodology areas on either side of congested corridor are identified separately and initially both are cleared as if there is no interconnection between the areas, and then the area which has highest price, draws electricity from the area with the lower price just as much as the capacity of the congested line will allow. Allowing this flow into higher price area will reduce prices in the higher price bid area and would increase prices in the lower price bid area depending upon the bid prices in the respective areas.

For a simple situation involving only two areas A and B is illustrated as under:

In the first step, all bids from both areas are aggregated together, similar to the System Price calculation. The common price, P_o, for both areas are established.

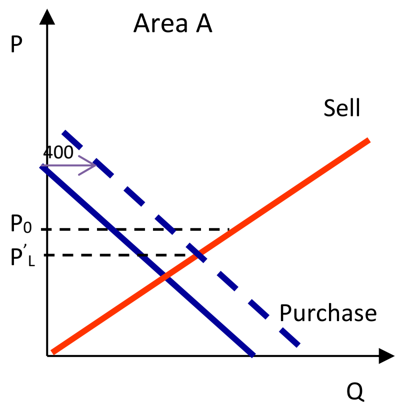
The bids are then aggregated in the area A and B separately. The aggregated curves could then look like this:

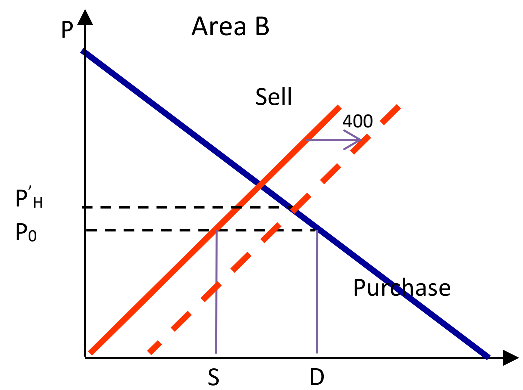


In this example the aggregated curves of area A intersect at a lower price, $P_{L,}$ than the common price, $P_{o.}$ Applying P_o in area A show that the sale at P_o is greater than the purchase at $P_{o.}$ Thus area A is surplus area. On the contrary, the aggregated curves of area B intersect at a higher price. P_H, than the common price $P_{o.}$ Applying P_o in area B show that the purchase at P_o is greater than the sale at $P_{o.}$ Thus, area B is a deficit area.

At this step, the transmission capacity is introduced in the Area Price calculation process. The power flow will always be form the surplus area to the deficit area, thus the transmission capacity from A to B will be used. The needed capacity is simply the difference between sale S_o and purchase D_o at price P_o in the deficit area. Assume that So=2000 and Do=2600, giving a difference of 600. If the available capacity from A to B is 600 or higher, the resulting area prices in both A and B will be $P_{o.}$

If the available capacity from A to B is 0, the area prices will be P_L in are A and P_H in area B. If the available capacity is anywhere between 0 to 600, e.g. 400, the available capacity is added to the purchase curve in the surplus area (A) and to the sale curve in the deficit area (B). This result in a parallel displacement of these curves, as shown below:





The area price will now be set at the intersection of the sale curve and displace purchase curve in area A, and at the intersection of the displaced sale curve and the purchase curve in area B. The transmission capacity is utilized so that the power flow exactly equals the available capacity. As a consequence of this, the area prices in A and B are leveled as much as possible. P'_H, P'_L are the new intersection points on movement of demand / supply curves. The difference between P_H and P_L is now lesser than it otherwise would have been if no power flow is possible between area A and area B) In case there is no constraint, price in area A and area B will be equal,

The Area Price calculation in now complete, including the congestion management described above. The main objective of the concept is fulfilled:

- All grid constraints are relieved
- The available capacities are fully utilized
- The sale-purchase balance requirement is satisfied in both areas (at different price levels).

3. Continuous Matching Algorithm

3.1. In the continuous trading session, the participants submit their buy and sell bids on a continuous basis during the trading period. The buyers and sellers get matched on continuous basis on a price-time priority. The seller with minimum price quote and buyer with the maximum price quote is considered as best seller and best buyer. Best five buy and sell bids, excluding the details of participants, is displayed to all the participants to show the market depth. The order matching rules followed in the case of continuous matching are provided as under:

3.1.1. The order is immediately checked if it can be matched.

3.1.2. The Orders are matched based on price and time priority. In case of more than one orders having the same price, the order with the earlier time will get the priority in matching.

3.1.3. The best buy order is matched with the best sell order when (buy price >= sell Price). For order matching, the best buy order is the one with the highest price and the best sell order is the one with the lowest price.

3.1.4. An order may match partially with another order resulting in multiple trades.

3.2. Following orders are available in the Continuous Trade Session.

3.2.1. **Timing Constraints**

I. Rest of day (Day): The order will be valid till the end of trading hours of that trading day.

II. Immediate or Cancel (IOC): The order placed will not be in pending status and will be cancelled immediately in case if not traded.

III. End of Session (EOS)

3.2.2. **Execution constraints**

I. Fill or Kill (FoK): This order will match the whole order OR delete the whole order.

3.3. **Example on Continuous matching Algorithm:** Let's assume the following buy and sell bids are available in the system, the best buy bid is offered by the buyer B3 i.e., 300 MW at Rs. 3300/MWh and best sell bid is placed by seller S1 i.e., 200 MW at Rs 3500/MWh. Since the price of best buy bid is less than the best sell bid, the orders will not get matched and show pending in the system.

Orders					
Buyer	Buy Price (Rs/Mwh)	Buy Qty (MW)	Seller	Sell Price (Rs/Mwh)	Sell Qty (MW)
B1	3000	500	S1	3500	200
B2	3200	400	S2	4000	300
B3	3300	300	S3	4200	500
B4	2800	200	S4	4400	400
B5	2500	300	S5	3200	500

In the above example, let's assume a new Seller S5 place a sell bid for 500 MW at Rs. 3200/MWh. As the price quoted by seller S5 will match with the price quoted by buyer B2 & B3 the transaction will take place between seller S5 and buyer B2 and seller S5 and buyer B3 as illustrated in the Table given below.

Orders						Trades			Pending Orders					
Buyer	Buy Price	Buy Qty	Seller	Sell Price	Sell Qty	Transaction	Trade Price	Trade Qty	Buyer	Buy Price	Buy Qty	Seller	Sell Price	Sell Qty
B1	3000	500	S5	3200	500	B3-S5	3200	300	B2	3200	200	S1	3500	200
B2	3200	400	S1	3500	200	B2-S5	3200	200	B1	3000	500	S2	4000	300
B3	3300	300	S2	4000	300				B4	2800	200	S3	4200	500
B4	2800	200	S3	4200	500				B5	2500	300	S4	4400	400
B5	2500	300	S4	4400	400									

4. Double-sided open/ close bid uniform price step auction Algorithm

4.1. In the double-sided open/ close bid uniform price step auction the matching of take place if there are crossing prices (buy price >= sell price) in the order book, that is, if the best bid price is equal to or higher than the best ask price. In that case, the equilibrium price is determined according to the following criteria:

1. **Maximum tradable volume:** The Equilibrium Price will be the price at which there is maximum tradable volume.
2. **Minimum unbalance:** If there is more than one price with equal value for maximum tradable volume, the price that leaves the least volume untraded at its level is chosen as Equilibrium Price.

4.2. If Auction Session has overlapping Buy and Sell orders resulting in at least 1 trade (if there are crossing prices i.e., best buy price >= best Sell Price) then the system would use the below mentioned principles to determine that Session's Auction Uniform Price. If system achieves more than one potential Auction Uniform Price by Principle 1, then the algorithm would move to Principle 2 to narrow down the options and so on. If any Principle achieves a single potential Auction Uniform Price, then that price would be assigned as that Session's Auction Uniform Price.

4.3. The uniform auction price calculation logic is explained below through an example

4.4. **Step-by-step application of the algorithm on Examples** Let's assume we have received various buy and sell bids during the trading hours for e.g. A, B, C, etc. The order book would be sorted on best buy and best sell basis at the end of the auction session as below:

BUY			SELL		
Order	Qty	Price	Price	Qty	Order
A	4,500	825	831	290	J
B	28,200	824	828	11,420	K
C	1,900	822	826	21,650	L
S	49,700	820	825	8,500	M
D	8,000	819	823	1,900	N
E	16,400	818	820	17,500	O
F	5,400	815	819	3,600	P
G	900	814	818	11,600	Q
H	4,575	812			R

1) Principle: Determining the Maximum Tradable Volume

The principle would establish the price(s) at which maximum tradable volume would be executed. There would be two steps involved in applying this principle.

STEP 1 - Determine the cumulative buy and sell quantities at each eligible price. The cumulative buy and sell quantities at each price for 'XYZ' are as follows:

BUY		Price	SELL	
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity
0	0	831	290	76,460
0	0	828	11,420	76,170
0	0	826	21,650	64,750
4,500	4,500	825	8,500	43,100
32,700	28,200	824	0	34,600
32,700	0	823	1,900	34,600
34,600	1,900	822	0	32,700
84,300	49,700	820	17,500	32,700
92,300	8,000	819	3,600	15,200
108,700	16,400	818	11,600	11,600
114,100	5,400	815	0	0
115,000	900	814	0	0
119,575	4,575	812	0	0

STEP 2 – Establish the total tradable volume at each eligible price (i.e., Maximum Quantity which may be traded at that each price). The total tradable volume at a price would be computed as 'Minimum of Cumulative Buy and Cumulative Sell quantity' at the respective price. The Maximum Tradable Volume (MEV) for each eligible price is as below:

BUY		Price	SELL		Maximum Executable Volume
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity	
0	0	831	290	76,460	0
0	0	828	11,420	76,170	0
0	0	826	21,650	64,750	0
4,500	4,500	825	8,500	43,100	4,500
32,700	28,200	824	0	34,600	32,700
32,700	0	823	1,900	34,600	32,700
34,600	1,900	822	0	32,700	32,700
84,300	49,700	820	17,500	32,700	32,700
92,300	8,000	819	3,600	15,200	15,200
108,700	16,400	818	11,600	11,600	11,600
114,100	5,400	815	0	0	0
115,000	900	814	0	0	0
119,575	4,575	812	0	0	0

Note: The Maximum Tradable Volume is the highest value amongst 'Maximum Tradable Volume' derived for all price points.

In this example, the maximum quantity that may be traded is 32,700 at prices 820, 822, 823 and 824. Therefore, as per Principle 1, the prices eligible for Auction Uniform Price Calculation are 820, 822, 823 and 824. The algorithm would eliminate all other price points as the potential Auction Uniform Price. To further narrow the choices for Uniform Auction Price, Principle 2 would be used to determine the Minimum Unbalance level.

2) **Principle: Establishing the Minimum Unbalance**

The second principle would ascertain the eligible price levels (from prices 820, 822, 823 and 824) at which the Unmatched Quantity is a minimum. The Minimum Unbalance at each price level is equal to 'Cumulative Buy Quantity – Cumulative Sell Quantity' as shown in the Table below.

BUY		Price	SELL		Maximum Executable Volume	Minimum Unbalance (CBO – CSO)
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity		
32,700	28,200	**824**	0	**34,600**	32,700	-1,900
32,700	0	**823**	1,900	**34,600**	32,700	-1,900
34,600	1,900	**822**	0	**32,700**	32,700	1,900
84,300	49,700	**820**	17,500	32,700	32,700	51,600

Ignoring the positive and negative signs, the lowest number in the Minimum Unbalance column is 1,900. The minimum Unbalance occurs at prices 822, 823 and 824. Therefore, as per completion of Principle 2, the prices eligible for Auction Uniform Price Calculation are 822, 823 and 824. The algorithm would further eliminate 820 as Auction Uniform prices and the algorithm would continue to the 3rd step to establish the Auction Uniform Price.

3) **Principle: Ascertaining where the Market Pressure exists**

The third principle would ascertain where the market pressure of the potential Uniform Auction Price prices exists on the buy or the sell side.

a. If all the potential Auction Uniform Prices have positive (+) Minimum Surplus then the market pressure is on the BUY side (Buyer's Market) and the Auction Uniform Price would be highest of the potential Auction Uniform Prices (Assuming that residual BUY pressure would likely cause the price to rise)

BUY		Price	SELL		Maximum Executable Volume	Minimum Surplus (CBO – CSO)	Multiple Minimum surplus with all +ve Surplus, so Buyer's Market and Uniform Price MAX (100,99) = 100
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity			
200	200	100	0	150	150	50	
200	0	99	150	150	150	50	

b. If all the potential Auction Uniform Prices have negative (-) Minimum Surplus then the market pressure is on the SELL side (Seller's Market) and the Auction Uniform Price should be lowest of the potential Prices (Assuming that residual SELL pressure would likely cause the price to fall)

BUY		Price	SELL		Maximum Executable Volume	Minimum Surplus (CBO – CSO)	Multiple Min surplus with all – Surplus, so Seller's Market and Uniform Price MIN (99,98) = 98
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity			
150	150	99	0	200	150	-50	
150	0	98	200	200	150	-50	

c. If the potential Auction Uniform Prices have either 'positive (+) as well as negative (-) Minimum Surplus' or 'If the Minimum Surplus is zero for each potential Price' then the algorithm should not further eliminate any potential Auction Uniform Prices derived from Principle 2 and should continue to Principle 4 carrying forward all the potential Auction Uniform Prices

BUY		Price	SELL		Maximum Executable Volume	Minimum Surplus (CBO – CSO)
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity		
32,700	28,200	**824**	0	**34,600**	32,700	-1,900
32,700	0	**823**	1,900	**34,600**	32,700	-1,900
34,600	1,900	**822**	0	**32,700**	32,700	1,900

In this example it is not yet possible to calculate as Auction Uniform Prices, since the potential Auction Uniform Prices have positive (+) as well as negative (-) Minimum Surplus. Therefore, at the completion of Principle 3, the Prices eligible for Auction Uniform Price Calculation are 822, 823 and 824 and the algorithm continues to the fourth and final step to establish the Auction Uniform Price.

4) Principle: Average of Price Points having Minimum Unbalance

The fourth and final principle determines Auction Uniform Price from the range of prices established in Principle 3 (from prices 822, 823, 824). There are two steps to this Principle. The first step should be to narrow the options of potential Auction Uniform Prices to 2 potential Auction Uniform Prices from within the derived price range

STEP 1

I. If the result of Principle 3 is a combination of positive and negative Market Pressure, then the algorithm should mark the two prices where the sign changes.

BUY		Price	SELL		Maximum Executable Volume	Minimum Surplus (CBO – CSO)
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity		
32,700	0	**823**	1,900	**34,600**	32,700	-1,900
34,600	1,900	**822**	0	**32,700**	32,700	1,900

II. If the Minimum Surplus for all potential Auction Uniform Prices is zero, then the algorithm should mark the highest and lowest prices within the potential price range as the potential Auction Uniform Prices.

BUY		Price	SELL		Maximum Executable Volume	Minimum Surplus (CBO – CSO)	Multiple Min Surplus with all 0, so Uniform Price AVG (110, 105) = 107.50
Cumulative Buy Quantity	Buy Quantity at Price		Sell Quantity at Price	Cumulative Sell Quantity			
1000	**1000**	110	0	1000	1,000	0	
1000	0	105	**1000**	1000	1,000	0	

In this example the sign at 822 is positive and changes to negative to 823. Therefore, the algorithm chooses 822 and 823 as the potential Auction Uniform Prices to be applied in this principle.

STEP 2

The Auction Uniform Price should be defined as the average of 2 derived potential Auction Uniform Prices i.e. 822 an 823. Auction Uniform Price = AVG (822,823) = 822.50

The determined official Auction Uniform Price would be **'822.50'**

Note: if determined Auction Uniform Price is not as per Product's Price Tick then Auction Uniform Price would be rounded off to the nearest product's price tick

All the matching orders would get traded at the determined Auction Uniform Price, regardless of the price actually stated when placing an order. The Order Priority for matching purpose would be determined on '**Price-Time**' Priority basis in TAM & GTAM contracts and 'Price-Pro-rata' basis in REC & ESCerts Contracts. All the Auction Session's Unmatched Pending Orders would get cancelled.

Note: If the Auction session has no overlapping Buy and Sell orders (i.e., Trades = 0), then the 'Three step Conditional Decision Rule Approach' to determine 'Auction Uniform Price' would not be referred.

4.5. **Example on allocation of quantity for REC & Escerts**: An illustration of price pro-rata basis allocation of quantity is shown below for ***REC & ESCERTs*** Contracts:

Step 1- Order Entry

Orders Details					
Order Entry	**Participant**	**Qty**	**Price**	**Result**	**Allotment (Pro rata)**
1.	Buyer1	50	5000	Selected	50
2.	Buyer2	20	4000	Selected	20
3.	Buyer3	10	2000	Rejected	0
	Total	**80**			**70**

1	Seller1	10	4000	Selected	5
2	Seller2	20	4000	Selected	10
3	Seller3	5	4000	Selected	3
4	Seller3	2	3000	Selected	2
5	Seller3	40	5000	Rejected	0

6	Seller4	10	2000	Selected	10
7	Seller5	20	2000	Selected	20
8	Seller6	20	1000	Selected	20
	Total	**127**			**70**

Step 2- Discovery of Price Equilibrium

Derivation of Equilibrium Price and Vol						
CB	**B**	**Price**	**S**	**CS**	**TV**	**UB**
50	50	5000	40	127	50	-77
70	20	4000	35	87	70	-17
70	0	3000	2	52	52	18
80	10	2000	30	50	50	30
80	0	1000	20	20	20	60

Price Discovered	**4000**
Volume Cleared	**70**

Step 3- Trade Details

Allocation based on Pro rata priority (PR)					
	Participant	**Participant**	**Qty**	**Price**	**Reason**
Trade1	Buyer1	Seller6	20	4000	Price Priority
Trade2	Buyer1	Seller5	20	4000	Price Priority
Trade3	Buyer1	Seller4	10	4000	Price Priority
Trade4	Buyer2	Seller3	2	4000	Price Priority
Trade5	Buyer2	Seller3	3	4000	Pro Rata Allotment
Trade6	Buyer2	Seller2	10	4000	Pro Rata Allotment
Trade7	Buyer2	Seller1	5	4000	Pro Rata Allotment
		MCV	**70**		

Step 3A- Pro Rata Working				
Pro Rata Working				
18	Pending Qty	WT	Allocation	Rounded Allocation
Seller1	10	0.2857143	5.14285714	5
Seller2	20	0.5714286	10.2857143	10
Seller3	5	0.1428571	2.57142857	3
	35	1	18	18

(1) **Note:** In case of rounding off difference at the time of pro rata allocation, the same will be adjusted in following manner:

(a) One unit each of the total rounding off error would be adjusted to/from the highest selected quantum in the descending order.

(b) However, total selected quantity along with rounding off adjustment will not exceed the total bid quantity of individual order.

5. Reverse Auction Algorithm

In Reverse Auction, buyer place its requisitions and sellers submits their offers against such requisition. In each reverse auction there would be one buyer and multiple sellers. The sellers will compete amongst themselves for the requisition made by the buyer. The auction takes place broadly in two steps: Initial Price Offer (IPO) and Reverse auction stage. The quantum required by the buyer is selected on bucket fill basis with best bid of the seller is selected first until the required quantum of buyer is achieved. The order matching rules for reverse auction session will have the following features:

5.1. **Process I: Auction Initiation by Buyer:**

Buyer initiates the process for auction by placing its requirement in the system in terms of Quantum, duration etc.

5.2. **Process II: Initial Price Offer (IPO) Stage**

5.2.1. **IPO Session:** Seller(s) will place their bids against the auction initiated by buyer. During this stage, seller(s) will be submitting their bid with nothing visible to the participating seller(s) except their own price and quantity. During IPO stage, seller(s) can increase, decrease price, quantity and can delete their bid also.

5.2.2. **Elimination Round:** Once IPO Session is closed, process of bid elimination will start in the following manner:

Step 1: Ranking of sell bids received under IPO in ascending order. If multiple sellers have quoted the same price, then the ranking shall be done on the basis of time priority basis.

Step 2: Elimination Round- The Bidder with the highest price bid in IPO stage will be called the H1 Bidder. The Highest Bidder(H1) will be eliminated provided that the total quoted quantity after elimination is not less than twice the Requisitioned Quantity

Step 3: After Closure of IPO, Lowest Rate will be published to eligible sellers.

5.3. **Process III: Reverse Auction (RA) Stage:**

After completion of IPO Stage, e- Reverse Auction will start. This process will follow the steps as mentioned below:

Step 1: Start of e- Reverse Auction as per Timelines for 120 Minutes with auto extension feature. The Exchange may specify any other timeline based on the market feedback.

Step 2: Only L1 price is published to market and no quantity is displayed against that.

Step 3: Modification of downward price is allowed, Rate can only be decreased by Re. 1/Mwhr or multiples thereof, and quantity must be non-zero and can only be increased by 1 MW or multiples thereof or as may be specified by the Exchange.

Step 4: Publishing of new L1 price with any change in the quoted price by the bidder.

Step 5: Reverse Auction lasts for 120 minutes from the start of e-Reverse Auction subject to Auto Extension as applicable.

Step 6: Auto extension of 10 Minutes, in case new L1 discovered in last 10 minutes of closing auction is less than from previous one. The Exchange may specify any other timeline based on the market feedback.

Step 7: Last Auto extension to be triggered latest by market closing time, beyond that no further extension of Reverse Auction to be considered.

Step 8: Ranking of these seller bids in increasing order of their bid price. In case two sellers have quoted the same price then ranking will be done on time priority basis.

Step 9: Selection of sellers as per their ranking i.e., from lowest to highest ranked seller where lowest rank is ascribed to the seller offering lowest bid price.

Step 10: Results of Reverse Auction Process.

5.4. **Illustration –** Reverse Auction considering the below offers submitted by different sellers during the bidding window allowed for the requisition.

5.4.1. **Requisition by Buyer:**

Requisition by buyer	Delivery Period	Period	Buyer Name	Minimum Quantity from Single Seller
200 MW	1-10-2019 to 31-10-2019	RTC	B1	20 MW

5.4.2. **Initial Price Offer (IPO) Stage:** Sellers submit their price and quantity against the requisition in the IPO session. The system rank the Bidders according to their price bids. The Bidder with the highest price bid is indicated as H1 Bidder. The Highest Bidder (H1) gets eliminated provided that the total quoted quantity after elimination is not less than twice the requisitioned quantity. The result after Closure of IPO stage with H1 rate will be published to eligible sellers.

Ranking	Sellers	Price (Rs./MWh)	Quantity (MW)	Status
H-5	Seller-4	3400	120	
H-4	Seller-3	3500	100	
H-3	Seller-1	4200	100	
H-2	Seller-2	5000	90	
H-1	Seller-5	6300	50	Eliminated

Based on bids submission received above after closure of IPO stage, the lowest price is offered by Seller-4 at Rs. 3,400/MWh for 120 MW and Seller 5 got eliminated as it has quoted highest price and by eliminating it, the condition of balance quantity being not less than twice of requisitioned quantity is satisfied. [Balance Qty post elimination (410 MW) ≥ Twice of requisitioned Qty (400MW)]

5.4.3. **Reverse Auction:**

(i) Auction Session

		L-1 Price: 3400
Sellers	**Price (Rs./MWh)**	**Quantity (MW)**
Seller-4	3400	120
Seller-3	3500	100
Seller-1	4200	100
Seller-2	5000	90

(ii) Result of Reverse Auction based on requisition of 200 MW:

Rank	Sellers	Initial Price (Rs./MWh)	Final Price (Rs./MWh)	Initial Quantity (MW)	Selected Quantity (MW)
L-1	Seller-3	3500	3350	100	100
L-2	Seller-4	3400	3360	120	100
L-3	Seller-1	4200	4000	100	
L-4	Seller-2	5000	5000	90	

In the above result the sellers have been ranked in increasing order of their final bid price. Based on the quoted price, L-1, L-2, L-3 & L-4 rank has been assigned to Seller-3, Seller-4, Seller-1 & Seller-2 respectively. Based on the requisition of 200 MW by the buyer, quantum of 100 MW is selected from Seller-3 out of the bid quantum of 100 MW and 100 MW of quantum is selected from Seller-4 out of the bid quantum of 120 MW based on the bucket fill methodology. In case two sellers have quoted the same price then ranking will be done on a time priority basis.

Version Control

S. No.	Version	Date
1.	Version 1	Nov – 21
2.	Version 2	Jan – 24
3.	Version 3	Jun – 24