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MCP Simulation and its Impact in Electricity Market

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Abstract*: For consumers economic point of view, competitive markets are highly required in order to meet their demands efficiently. Therefore, this work formulates bidding analysis model in order to meet the demand and supply of consumers in electricity markets in day-ahead markets. In this, single side bidding models scenario has been discussed with a constant power demand using fuel cost linear curves. The objective of singe side bidding is to find out the market clearing price (MCP) and respective generation quantity of the entire supply participants. The numerical case study has been presented with five suppliers and a fixed power demand on hourly basis up to 24 hours.

***Keywords*: Competitive Electricity Market, MCP Simulations, Pool Based Market, Power Exchange.**

I. INTRODUCTION

After 90s, countries all around the world moving towards deregulation for taking care of the social and economic benefits of their nation. The monopolistic market is shifted to oligopolistic market in order to enhance the competition. Pool based market structure is one of the best market structure to enhance the competition [1]. In Pool based market central auction process has been done in which all the sellers and purchasers come together for their respective bidding. All the market players both generators and buyers will submit their energy and amount corresponding to their requirement either in blocks or in linear curve form. All the market players also have some market obligations in term of finance and energy quantity. System operator (SO) have a big role in market clearing and some other guidelines related to electricity and some other socio economic constraints [2].

At present, the auction process in electricity creates multiple options for both the generators as well as for the consumers or customers point of view. The growth in such type of market has both technical as well as social impact. In this, the price of electricity will reduces, increase the efficiency of supply and also open the door for new participants in electricity supply industry. Actually, deregulation comes in this sector because of certain other areas specially experience from energy and telecommunication sector. The settlement and storage of electricity is one of the major issues in electricity sector.

Fushuan Wen et. al [5] has worked on pool based electricity market in which each supplier and consumer bids is assumed to be function of linear curve. The completion has been created in order to maximize the social welfare and economy. The market has been formulated in a stochastic optimisation environment using Monte-carlo equation. Salem Al-Agtasha et. al [6] has presented a oligopolistic competitive market to optimise the social welfare and the market operates for time spam of multiple hours. In this, Augmented Lagrangian function has been used for optimal scheduling of power system. Shijun Fu et. al [7] has designed emission market on the basis of environmental aspects to meet the demand in competitive market. This presented mechanism has divides the emmision market into two parts initial and secondary. The aim of presented market is to reduce the CO2 emission. Zhen Liu et. al [8] has designed an electricity price mechanism in order to optimize power generators in market and also reduce the emission pollution emissions has been the key to deepening the reform of the electricity market. In this, two measures has been adopted firstly; a semi-random mitigation of power between generator and purchaser. Subsequently, then the products of electricity have been divided into two parts corresponding to generation and emission. Deepak Singhal et. al [9] has been worked on price forecasting in deregulated market with the help of neural networks. In this, the accurate forecasting will help in online trading part and e-commerce part. Therefore, in this paper a competitive environment based model has been designed with fixed demand and no. of generators at supply side. Each generator will take part in auction and submit their energy with price. This paper also shows how price of electricity will change if the demand of electricity is changing. In section 2, the process and role of Power Exchange (PX) has been discussed. This section also limelight auction based market and auction process. Section 3, detailed about case study involved in auction for electricity. In section 4 results of working model with its impact has been detailed. Finally at the end section V concludes the present work.

II. PROCESS INSIDE POWER EXCHANGE (PX)

In the PX based electricity sector structure [5], the electricity is supplied though the pool based trading mechanism. In the pool, electricity market participants like: suppliers submit their generation with their supply cost and distributors submit their demand with purchasing cost. Finally, at the end, matching of generation and demand is done through system operator in the PX [7]. In this type of market, the supply curves are the function of fuel cost incremental curves i.e. basically these curves are the function of energy price.

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This process aggregates either sides' curves into aggregate supply and demand curve or aggregate supply curve for a fixed demand on hour or half an hour basis. In this auction base structure, two type of mechanism have been involved: single side bidding (SSB) auction and double side bidding (DSB) auction. Through this process, the PX will be able to find the equilibrium point where both sides' curves will intersect. This intersection point defines the price of electricity and quantity of electricity of each bidder. For easy understanding of the whole process, this paper considers only SSB process with a fixed electricity demand [1], [2], [5], [7] & [12].

A. Concept of Auction based market

The price comes out after intersection of generation and demand curves is called equilibrium point inside the electricity auction based market. The optimum price obtained at intersection of aggregated generation and load (demand) curve is called Market Clearing Price (MCP) and the quantity of generation at that point known as Market Clearing Volume or Quantity (MCV or MCQ). At this intersection curve, both generators sell their generation and customers or customers purchase that generation and both have to satisfy under SO conditions. This complete process of clearing has been shown in Figure 1.

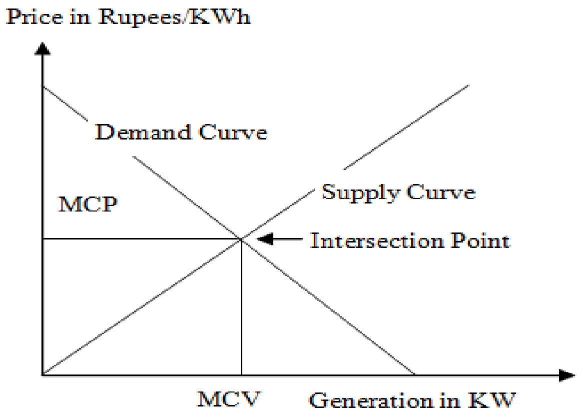

Fig. 1 Auction curves for both sides

B. Auction Process

In this, SSB process has been involved in which supplies are bid for their generation quantity and price to the PX in order to meet fixed electricity demand. Let us suppose, Ns defines the no. of supply side or generator bidders. For i^{th} generator or supplier the bidding curve is defined by the equation $C_i = X_{it} + Y_{it} PG_{it}$ is submitted to for each hour to Power Exchange [5], [2]. Here PG_{it} is the total power generated by the i^{th} generator and a_{it} & b_{it} are the non negative bidding parameters. The PX is utilized to evaluate MCP and the total generation quantity provided by each generator to meet the demand has been given by the equations (1):

$$MCP = \frac{PD_t}{\sum_{i=1}^{N_s} \frac{1}{Y_{it}}} \quad ------(1)$$

Y_{it} is actually defines the slope of generation curve with price for i^{th} generator. The demand of power is denoted by PD_t for every hour of the day.

The quantity of power awarded to each generator is

$$SQ_{it} = \frac{MCP}{Y_{it}} \quad --------- --(2)$$

SQ_{it} is generation quantity of each supplier and then the revenue (R) generated by i^{th} generator to meet the demand for a fix time period t^{th} has been evaluated by the equation (3):

$$R_{it} = SQ_{it} * MCP_t \quad ----------- (3)$$

Total Revenue (TR) obtained by N_s generators is evaluated by the equation (4):

$$TR = \sum_{i=1}^{N_s} MCP_t * SQ_{it} \quad ------ \quad (4)$$

$$SQ_{i\,min} <= SQ <= SQ_{i\,max} \quad i = i, ------ N_s$$

If the generation quantity exceed beyond this $SQ_{i\,min}$ & $SQ_{i\,max}$ range then the particular generation or supplier is not been the part of electricity auction process.

III. CASE STUDY OF SSB PROCESS

In this case study five different bidding inputs have been considered for the analysis purpose for electricity market point of view with uniform approach of price. Actually, all the bidders are supposed to be used for increasing the competition to achieve the optimum price so that consumers can be benefitted. The input linear bidding parameter has been given in Table 1. In this, SQmax. defines the maximum value of supply power generation and SQmin. defines the minimum supply generation i.e. SQmax. & SQmin. utilized to define range of power supply. The linear supply generation curves on the behalf of bid price with power generation demand of 300 KW have been shown in Figure 2.

Table 1: Linear Bidding Data Curves

Supply Bidders	Y_{it}, Rs./KW	SQmax.	SQmin.
Bidder 1	0.13	100	20
Bidder 2	0.17	100	20
Bidder 3	0.18	100	20
Bidder 4	0.19	100	20
Bidder 5	0.23	100	20

IV. WORKING MODEL RESULTS

From the figure 2, the MCP obtained is 10.438 and the quantity of power generated to meet 300 KW power demand has been given in table in Table 5.2. Now consider that the some power let us say 50 KW has been taken from local power generator then the MCP will be reduced as given in table 2. The price is 8.698 and the overall generation cost to meet this 300 KW power demand is also get reduced. The supply quantity has been defined by the given equation (6) and this equation is also used to find the aggregate supply curve. The figure 3 shows the aggregate supply curve with fixed demand of 300KW at MCP of 10.438. The slope of aggregate supply curve is 0.03479.

$$\Delta SQ_i = \frac{\Delta p}{Y_i} \quad ----------------- (6)$$

The total amount in Rs. at MCP of 10.438 is 3131.393. When the demand is met by the local generator then the total amount at MCP of 8.698 is 2436.0637 as shown in Table 2.

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The possibility of monopoly is SSB scenario is very less. The MCP is highly variable to the demand if the demand is reduced to 50 KW them MCP is also get reduced (1.7397) as given in table 3.

In Table 1, the input data from all five generators with generation quantity for 24 hours have been given. In order to the the impact of PD, the PD data for 24 hours has also been given in table 4. This table shows if the PD is more, then MCP will automatically increase and if PD is decreasing then the MCP will also decrease. This shows that the MCP is highly dependent variable of PD. In Table 5, the revenue in Rs. corresponding to supply quantity and MCP has been given.

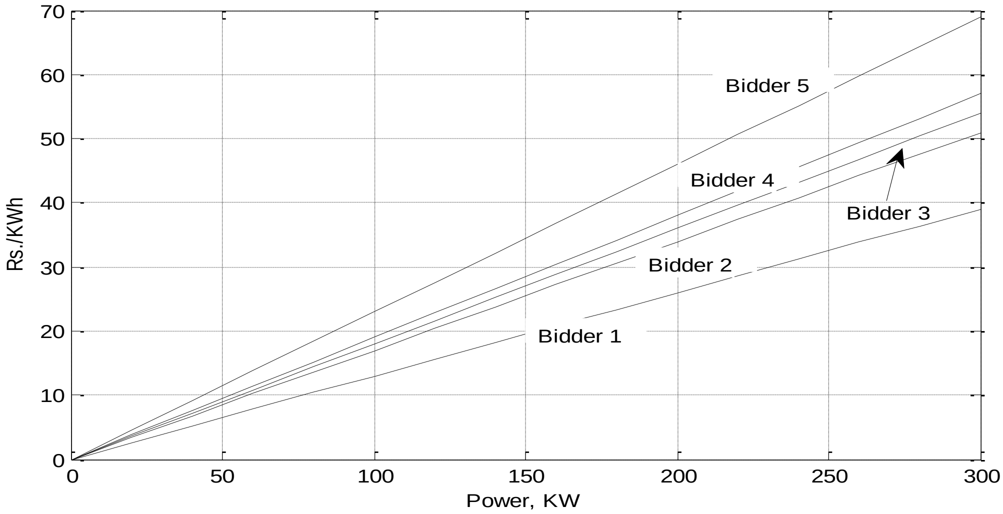

Fig. 2: Linear Generation Curve on the behalf of bid price

Table- 2: Output and Payment at Different Cases

Bidders	Generated power in KW at MCP 10.438	Payment at MCP 10.438	Generated power in KW at MCP 8.6983	Payment at 8.6983	Payment at 10.438
	PD=300		*1<ms<10*		
Bidder-1	80.2921	838.0875	66.9101	582.0052	698.4076
Bidder-2	61.3999	640.8904	51.1666	445.0628	534.077
Bidder-3	57.9888	605.2854	48.324	420.3371	504.4059
Bidder-4	54.9367	573.4283	45.7806	398.2141	477.8579
Bidder-5	45.3825	473.7016	37.8188	328.9595	394.7526
Local Generation	0	0	50	261.485	521.9
Total	300	3131.393	300.0001	2436.0637	3131.401

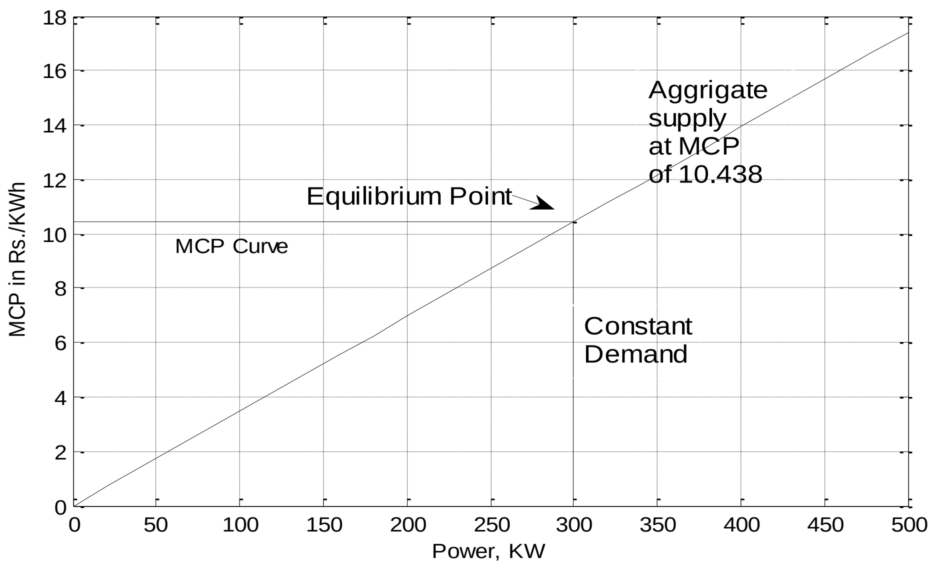

Fig. 3: Aggregate supply curve with fixed demand at MCP of 10.438

Table- 3: Output and Payment at Different Cases

Bidders	Output KW At 1.7397	Payment At 1.7397
	ms<1	
Bidder-1	13.382	23.2802
Bidder-2	10.2333	17.8025
Bidder-3	9.6648	16.8135
Bidder-4	9.1561	15.9286
Bidder-5	7.5638	13.1584
Total	50	86.9832

Table- 4: Inputs Bid Data and MCP

Time	Bidder 1		Bidder 2		Bidder 3		Bidder 4		Bidder 5		PD	MCP
	Y	SQ_{max}-SQ_{min}	*Y*	SQ_{max}-SQ_{min}	*Y*	SQ_{max}-SQ_{min}	*Y*	SQ_{max}-SQ_{min}	*Y*	SQ_{max}-SQ_{min}	*MW*	*In Rs.*
00:01	0.1	20-100	0.17	20-100	0.18	20-100	0.19	20-100	0.23	20-100	150	4.8310
01:00	0.1	20-100	0.17	20-100	0.18	20-100	0.19	20-100	0.23	20-100	160	5.1531
02:00	0.1	20-100	0.17	20-100	0.18	20-100	0.19	20-100	0.23	20-100	160	5.1531
03:00	0.1	20-100	0.17	20-100	0.18	20-100	0.19	20-100	0.23	20-100	160	5.1531
04:00	0.12	20-100	0.18	20-100	0.2	20-100	0.2	20-100	0.24	20-100	170	6.0594
05:00	0.12	20-100	0.19	20-100	0.22	20-100	0.21	20-100	0.26	20-100	185	6.9158
06:00	0.13	20-100	0.19	20-100	0.23	20-100	0.21	20-100	0.27	20-100	230	8.9254
07:00	0.14	20-100	0.2	20-100	0.25	20-100	0.24	20-100	0.28	20-100	270	11.306
08:00	0.14	20-100	0.2	20-100	0.25	20-100	0.24	20-100	0.29	20-100	300	12.627
09:00	0.14	20-100	0.2	20-100	0.25	20-100	0.24	20-100	0.29	20-100	280	11.785
10:00	0.12	20-100	0.19	20-100	0.23	20-100	0.22	20-100	0.27	20-100	260	9.9261
11:00	0.12	20-100	0.19	20-100	0.21	20-100	0.22	20-100	0.24	20-100	240	8.8657
12:00	0.11	20-100	0.19	20-100	0.21	20-100	0.22	20-100	0.24	20-100	200	7.1869
13:00	0.11	20-100	0.19	20-100	0.21	20-100	0.22	20-100	0.24	20-100	200	7.1869
14:00	0.12	20-100	0.19	20-100	0.21	20-100	0.22	20-100	0.24	20-100	220	8.1269
15:00	0.11	20-100	0.19	20-100	0.21	20-100	0.24	20-100	0.24	20-100	220	8.0147
16:00	0.12	20-100	0.19	20-100	0.23	20-100	0.25	20-100	0.24	20-100	200	7.6596
17:00	0.13	20-100	0.2	20-100	0.23	20-100	0.25	20-100	0.26	20-100	180	7.2328
18:00	0.13	20-100	0.2	20-100	0.23	20-100	0.25	20-100	0.27	20-100	220	8.8911
19:00	0.13	20-100	0.2	20-100	0.25	20-100	0.26	20-100	0.3	20-100	260	10.891
20:00	0.12	20-100	0.23	20-100	0.26	20-100	0.27	20-100	0.3	20-100	290	12.306
21:00	0.12	20-100	0.21	20-100	0.26	20-100	0.26	20-100	0.3	20-100	285	11.815
22:00	0.11	20-100	0.19	20-100	0.24	20-100	0.22	20-100	0.28	20-100	220	8.2589
23:00	0.1	20-100	0.18	20-100	0.21	20-100	0.19	20-100	0.23	20-100	200	6.6826

Table- 5: Supply Quantity of each Bidder and Revenue

Time	Bidder 1		Bidder 2		Bidder 3		Bidder 4		Bidder 5		Total	Total
	SQ	*R*	*SQ*	*R*	*SQ*	*R*	*SQ*	*R*	*SQ*	*R*	*SQ(MW)*	*R in Rs.*
1	48.310	233.4	28.4181	137.3	26.839	129.7	25.426	122.8	21.004	101.5	150	874.664
2	51.531	265.6	30.3127	156.2	28.628	147.5	27.121	139.8	22.405	115.5	160	984.506
3	51.531	265.6	30.3127	156.2	28.628	147.5	27.121	139.8	22.405	115.5	160	984.506
4	51.531	265.6	30.3127	156.2	28.628	147.5	27.121	139.8	22.405	115.5	160	984.506
5	50.495	306	33.6633	204	30.297	183.6	30.297	183.6	25.247	153	170	1200.1
6	57.632	398.6	36.3994	251.7	31.435	217.4	32.932	227.8	26.599	184	185	1464.44
7	68.657	612.8	46.9762	419.3	38.806	346.4	42.502	379.4	33.057	295.1	230	2282.86
8	80.757	913.1	56.5304	639.1	45.224	511.3	47.108	532.6	40.378	456.5	270	3322.64
9	90.195	1139	63.1371	797.3	50.509	637.8	52.614	664.4	43.542	549.8	300	4088.23
10	84.182	992.1	58.9280	694.5	47.142	555.6	49.106	578.8	40.640	479	280	3579.97
11	82.717	821.1	52.2428	518.6	43.157	428.4	45.118	447.9	36.763	364.9	260	2840.8
12	73.881	655	46.6617	413.7	42.217	374.3	40.298	357.3	36.940	327.5	240	2367.78
13	65.336	469.6	37.8262	271.9	34.223	246	32.668	234.8	29.945	215.2	200	1637.4
14	65.336	469.6	37.8262	271.9	34.223	246	32.668	234.8	29.945	215.2	200	1637.4
15	67.724	550.4	42.7732	347.6	38.699	314.5	36.940	300.2	33.862	275.2	220	2007.92
16	72.861	584	42.1830	338.1	38.165	305.9	33.394	267.7	33.394	267.7	220	1983.25
17	63.830	488.9	40.3137	308.8	33.302	255.1	30.638	234.7	31.915	244.5	200	1731.92
18	55.637	402.4	36.1644	261.6	31.447	227.5	28.931	209.3	27.818	201.2	180	1481.92
19	68.393	608.1	44.4555	395.3	38.656	343.7	35.564	316.2	32.930	292.8	220	2176.04
20	83.780	912.5	54.4575	593.1	43.566	474.5	41.890	456.3	36.305	395.4	260	3091.79
21	102.55	1262	53.5075	658.5	47.333	582.5	45.580	560.9	41.022	504.9	290	3858.95
22	98.462	1163	56.2642	664.8	45.444	536.9	45.444	536.9	39.384	465.4	285	3652.41
23	75.081	620.1	43.4684	359	34.412	284.2	37.540	310.1	29.496	243.6	220	2036.98
24	66.826	446.6	37.1255	248.1	31.821	212.7	35.171	235	29.054	194.2	200	1536.52

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V. CONCLUSION

The work presented in this paper detailed about the working of competitive electricity market. SSB process has been analysed with a fixed demand. The role of PX in the market has also been discussed. By the auction process it has been analysed and found that the price is highly variable to the demand. If demand of electricity will increase the price will decrease and vice versa. As detailed in Table 5 if the demand is 50 KW then price of electricity is very less 1.7397. For the auction process and analysis five supply side bidders has been considered for mitigation of a fixed demand. For further analysis of electricity price and generation of each bidder, 24 hours case study has been presented.

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