ORIGINAL RESEARCH PAPER

Engineering

POWER MARKET TRANSPARENCY INDEX WITH VARIABLE DEMAND

KEY WORDS: Scheduled power, forecasted wind power, reserviour level, Market clearing price (MCP), Power Market Transparency Index (PMTI)

Neeraj Kumar Research Scholar Department of Electrical Engineering B. M. University, Rohtak (Haryana) India

Rohit Verma Associate Professor National Power Training Institute Faridabad (Haryana) India

ABSTRACT

Power Market transparency is required because big size generators and consumers can easily manipulate the market if the number of participants in a Power trading market is small. In this paper, authors have developed a simple model of quantifying the various activities in a power market in tangible terms which are generally considered as intangible, leading to a measurement model of power market transparency. A Power Market Transparency Index (PMTI) has been modeled which indicates power market transparency and is dependent on a number of factors such as number of bidders, scheduled and unscheduled power, scheduled and unscheduled meteorological events and climatic conditions, reservoir level predictions etc. The results indicate that market design by taking PMTI can have good effects, even for sophisticated institutional customers. This work can help the financers, like banks, financial Institutional etc for selecting a country for their fund flow decision in Power Markets. This instills participant's confidence in the power market. Calculations of MCP have been done with the help of Matrix Laboratory.

1. INTRODUCTION

Deregulation or restructuring in Electricity industry is spreading across the world with the aim to bring reliability, desired quality of power to the customers at an economical rate and transparency in power markets [1]. The introduction of the deregulation has brought several new entities in the electricity market. Different generating companies makes contract with different distribution companies to supply power, with the bulk consumers or sell the power in a pool in which the electricity traders and consumers participate [2].Electricity business from its inception, was predominantly a monopolistic business, mostly operated by Governments. Electricity sector reform across the world has intensified in the last two decades. Most of the countries whether developed or developing have enacted reformist electricity regulation and have recognized electricity as a commodity just like any other commodity. After deregulation most of the countries have kept electricity transmission business under Governments or Governments controlled sector, to provide fair and open access of transmission capacity to all. In electricity sector, power market transparency is required because big size generators can easily manipulate the market if the number of participants in a power trading market is small. Here, the transparency means all the information that can affect the prices should be made publicly available. Transparency means giving all the participants' equal access to relevant information is prerequisite for a well functioning, competitive and efficient market. It engenders trust, lower barriers to entry and attracts new entrants all of which helps to generate liquidity. A large number of participants are there in the Power Market and their stakes are high. If there is a indicator of market transparency, it may help the power market participants to foresee the risks involved in a particular market. In this paper, incidences in the power market have been expressed in tangible terms which may finally lead to making up of a Power Market Transparency Index (PMTI). PMTI is dependent on a number of factors such as number of bidders, scheduled and unscheduled power, meteorological events & climatic conditions and reservoir level predictions etc. Power market transparency can be linked to number of bidders in a power market. If power market regulations such as open access, ceiling of minimum power for bidding etc. is consumer friendly, it increases the number of bidders which further leads to market stabilization and liquidity. Climatic conditions have a direct impact on power demand. If the meteorological events predictions are more accurate then quantity of scheduled power is more and if it is more inaccurate the quantity of unscheduled power is more. Hence correctness of meteorological events and predictions may be linked in tangible terms to the quantity of scheduled and unscheduled power. Reservoir level variation in a country, on which hydro power is more dependent, may vary the market prices of power. If reservoir level predictions are accurate then it may lead to lesser hydro unscheduled power, leading to a more predicted power price. In a transparent power market both seller and buyer are promoted to take market position as a transparent player. However the price transparency can have negative impact on prices, increasing the buyers and sellers to team together for price manipulation and temporary benefit resulting in less price transparent regime. By providing protections for investors, transparency encourages greater participation in the power markets, and thereby enhances the liquidity of those markets. Encouraging the global fund flow in that particular market.

II. POWER TRADING MODEL

Electricity trading though have many similarities with the commodity trading, it has some special nature[4] that it cannot be stored , constricting transmission capacity low elasticity in demand, balance between generation and demand etc which results in price volatility of electricity. Hence electricity trading market should rely on specifically designed electricity tool. In any trading activity, there are two participants trading directly in bilateral manner or through an exchange .Electricity trading arrangement in U.S.A.,U.K.,Australia, Newzela nd,Geramany ,Brazil,Chillie,Nordic countries and its neighbors has undergone huge transformation in last twenty years. In India electricity trading on Exchanges has commenced since last 7 years. Power Exchange(PX) transact business electronically with market participants submitting their bids and offers with an Power Exchanges server and PX determines the market clearing price(MCP) by intersecting the total of demand and supply curves. In case of power market settlements

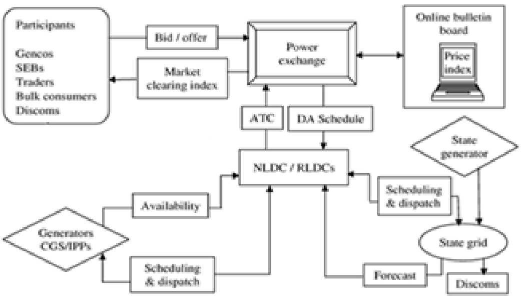

Fig.1Competitve power trading model

III. MARKET CLEARING PRICING RULES

In electricity auction three important pricing rules are there out of which two are more predominantly used in real time market a) market clearing rules with single or uniform price and b) Market clearing rule with pay as bid price. The former is most commonly used in power market [5]. In this methodology the power sellers would receive MCP for their power even if they bid less than that price and all the electricity buyers would pay the MCP even if they bid more than that price. As per later rule each market each market participants with winning bid pays or is paid at the price of his bid. This system does bidding on the basis of price guessing and not on the basis of MCP. In the reforming global power market, after deregulation uniform pricing system is mostly chosen because it is perceived to encourage the bidders to reveal their actual cost.

IV. METHODOLGY

DETERMINATION OF MCP:- The MCP is obtained by intersecting the total of demand and supply curves[5]. At this MCP the electricity suppliers or generators and electricity consumers or demand creators are contented and this would provide sufficient power from accepted sale bids to satisfy all the demand bids. The generators sale bids are usually arranged in descending order of price with quantity of electricity offered. However the purchased order price is placed in ascending order of price mentioning the quantity of electricity [15]. At the market clearing price (MCP) total demand bids would be equal to total generators bid or sale bids. In the market both supply and demand bid are either block or linear bids i.e. they should be of same type. In this paper MCP has been analyzed for the linear bid cases.

$Q_1(p)$ = MW generated by Bidder 1 at a price'p' \$/MWH

$$Q_1(p) = \frac{p}{m_{s1}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where m_{s1} is the slope of linear supply curve of bidder1. Similarly

$$Q_2(p) = \frac{p}{m_{s2}} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where Q_2 (p)=MW generated by Bidder 2 at a price' p' \$/MWH

m_{s2} is the slope of linear supply curve of bidder 2.
Likewise, combined supply curve for 'N' bidders will be

Q(p)= Q1 (p)+Q2 (p)+ …………upto N

$$= \frac{p}{m_{s1}} + \frac{p}{m_{s2}} + \ldots\ldots\ldots \text{upto } N$$

$$= p \sum_{i=1}^{N_s} \frac{1}{m_{si}} \quad \ldots\ldots\ldots\ldots (3)$$

Where N_s is No. of suppliers and m_{si} is the slope of supply curve
For the fixed demand D, the market clearing price (p*) will be obtained by solving the following equations.

$$D = p^* \sum_{i=1}^{N_s} \frac{1}{m_{si}} \ldots\ldots\ldots\ldots \quad (4)$$

If there are Nd customers who are participating into the market. Then the market clearing price (p*) can be obtained by solving the equation [15].

$$\text{Market Clearing Price } (p^*) = \frac{\sum_{i=1}^{N_d} \frac{Q_o}{m_{di}}}{\sum_{i=1}^{N_s} \frac{1}{m_{si}} + \sum_{i=1}^{N_d} \frac{1}{m_{di}}} \quad (5)$$

Where mdi is slope of demand curve &Qo is the price axis intercept of demand curve varies with types of consumers.

A. ANALYSIS

In this paper a uniform pricing approach has been considered. Here three cases have been taken with different number of bidders [12], [13]. Table 1 shows the msi i.e. slope of supply curves for 5 bidders, 7 bidders and 10 bidders respectively. The lower and upper limit of different generators bidder are also given and Case 4 Linear bid data for demand with 10 consumers given in Table 2.

Table No-1 m_{si} (\$/MW h^2) slope of supply curves with different bidders

Q_{max}=Maximum Power generated in MW and Q_{min}=Minimum Power generated in MW

	m_{si}	Q_{max}	Q_{min}
Case-1 for 5 bidder			
Bidder -1	.21	100	10
Bidder-2	.30	50	05
Bidder-3	.26	50	07
Bidder-4	.27	50	07
Bidder-5	.29	50	05
Case-2 for 7 bidder			
Bidder -1	.25	50	07
Bidder-2	.20	100	10
Bidder-3	.22	100	10
Bidder-4	.24	50	05
Bidder-5	.26	50	07
Bidder-6	.28	100	10
Bidder-7	.30	100	10
Case -3 for 10 bidder			
Bidder 1	.22	50	10
Bidder-2	.24	50	05
Bidder-3	.26	100	10
Bidder-4	.28	100	10
Bidder-5	.30	50	05
Bidder-6	.32	50	07
Bidder 7	.34	100	10
Bidder-8	.36	100	10
Bidder-9	.38	50	05
Bidder-10	.40	50	05

Table no-2 mdi slope of demand curve with 10 consumers

	m_{di}(\$/MW h^2)	Q_o(\$/MW h)
customer -1	0.30	10
customer-2	0.31	11
customer-3	0.33	13
Customer-4	0.33	14
Customer-5	0.28	15
Customer-6	0.32	15
Customer-7	0.34	16
Customer-8	0.36	17
Customer-9	0.38	18
Customer-10	0.40	19.5

Table no-3 Cumulative supply curve (CSS) with different demand for 5,7,10 Bidders

		D=100	D=150	D=200
	CSS	P*(MCP)	P*(MCP)	P*(MCP)
Case-1	19.09	5.2383	7.8575	10.4767
Case-2	28.47	3.5124	5.2687	7.0249
Case-3	33.47	2.9877	4.4816	5.9755

Table No-4 MCP with 8 quarter demand bid during the day

Time interval 1 quarter= 3 hours	Demand(MW)	MCP for 5 bidders	MCP for 7 bidders	MCP for 10 bidders
1st qtr	101	5.2898	3.5476	3.0176
2nd qtr	103	5.6040	3.7583	3.1969
3rd qtr	125	6.0754	4.0745	3.4658
4thqtr	148	8.1704	5.4795	4.6609
5th qtr	160	8.9036	5.9712	5.0792
6th qtr	200	10.4748	7.0249	5.9755
7th qtr	186	9.9511	6.6737	5.6767
8th qtr	102	5.3422	3.5827	3.0475

B. POWER MARKET TRANSPARENCY INDEX (:(τThe term market transparency is used to express the ease with which all market participants can observe the market information in a trading process. Here the transparency is defined in a very simple way, however in a real time market it is not so simple and results in complexity . The basic question arises that which information are observable. In one definition market is said to be transparent if market clearing price(MCP) can be discovered . To decide market transparency we also need to know the ease with market information can be observed by a market participants; whether the information is understandable only to traders or potential traders or price setting agents or to customers This issue is very important because information available in the power market can decide the strategies of participants. Power market participants strategies will depend on the transparency of that particular market and market balance or imbalance will be directly related to degree of transparency. Price discovery or process of finding MCP is a crucial function of any trading mechanism. Price discovery is influenced by market transparency. Lower the transparency in market higher are chances of price manipulation. PMTI is dependent on number of factors.

C. ANALYSIS OF POWER MARKET TRANSPARENCY INDEX ((ד

With the reforming global power market various strategies and techniques are required to maintain system reliability and transparency. In this paper we introduce a new term called Power Market Transparency Index or PMT Index (PMTI) which includes various factors by which demand and supply are affected. One of them is Market Clearing Price Index or MCP Index. The MCP index is calculated with the help of MCPs for different number of bidders. Other factors are quantity of scheduled power, unscheduled power, Climatic conditions, scheduled meteorological events, unscheduled meteorological events, Reservoir level announcements. To encourage power market competition and to deliver electricity from generator to consumers, strengthening and expansion of transmission system gains utmost importance to relieve clogging of transmission system and to provide level playing field to all market participants. PMTI developed in this paper can be used as a tool for measurement and comparison of various global power markets by market participants. Power market participants can use this PMTI tool in their decision making process for finding specific power project in a country by ranking its transparency by using this tool. The proposed scheme will be helpful in identifying and evaluated potential investment destination.

PMTI will depend on various factors which can be expressed in the following expression:

Power Market Transparency Index (= (דF_1+ F_2+ F_3+ F_4

A. MCP BASED FACTOR (F_1)

Most of the countries now a days have national power exchange which encourages power trading in various region of that country as well as it facilitate international power trading also resulting in optimal utilization of resources available. Power Exchange (PX) determine the prices without disclosing the credentials of bidder and match demand and supply of the electricity. India has two operating power exchanges namely IEX and PXIL, Nordic countries have PX named Nord Pool in which power is traded internationally amongst the participating countries. UKPX and APX are operating in the region of U.K. Power next and OMEL is operating in South Western Europe region. In this paper example of India has been taken and similar extrapolation can be done for other power market. Total electricity traded volume in day ahead market at PXIL and IEX is 3% of total power generation in India. The total generated power in India from all sources are 995157 MU as on 31 March 2014 [22] and contribution from coal is 85%, Hydro 9% and wind 2.5%[18]. Here the factor F1 is determined by multiplying a weight age factor Wmcp which is taken as 3%, as total power traded on electricity exchanges by MCP method is 3%. Its value is calculated as given below.

$$F_2 = \frac{1}{\text{MCP Index}} * W_{mcp}$$

Here W_{mcp} = 3% (weight age factor for MCP Index and this is total traded power on the power exchanges of a country).

The remaining percentage weight age i.e. (100-3=97) is given to other sources of electricity generation according to their contribution in India. The formula for calculating the same is as under:-

$$W_s = P_s * (100 - W_{mcp})$$

Here W_s =percentage of weight age for different generation sources such as coal based power, hydro power and wind power etc.

P_s=percentage of actual electricity generation in India from different sources

B. COAL BASED GENERATION PREDICTION(F2)

Inadequate coal availability and increasing international coal prices are threatening to sustain the required plant load factors (PLF's) in coal based power plant. In developing country like India no go embargo set up jointly by Ministry of Environmental and forest (MOEF) and coal ministry may also affect the schedule power generated by coal based power plant. Several coal based plants continue to operate with a critical coal stock of less than seven days in India. These information help in increasing higher generation costs and resulting in increased domestic power tariffs. Due to these factors in electricity markets demand side bidder will not show their keen interest in these companies and switch over to some other electricity producer.

$$F_2 = \frac{\text{Quantity of Scheduled Power based on coal} - \text{Quantity of Unscheduled Power based on coal}}{\text{Quantity of Scheduled Power based on coal}} * W_2$$

Here W2 is the weight age factor for coal based generation. In India coal based generation is the dominant amongst all the sources of generation. Its percentage is 85% of the total generation of electricity from all sources in India. So W2=0.85*(100-3%).

Table- 5 For Calculation of factor F_2

Sr. no.	Coal based power(MU)	Unscheduled power(MU)		$\frac{Q_{csp} - Q_{ucsp}}{Q_{csp}}$	F2
		In %	In calculated form		
1	845883	5	42294.15	0.95	0.783
2	845883	7	59211.81	0.93	0.767
3	845883	8	67670.64	0.92	0.759
4	845883	9	76129.47	0.91	0.750
5	845883	10	84588.3	0.9	0.742
6	845883	12	101505.96	0.88	0.726
7	845883	11	93047.13	0.89	0.734
8	845883	6	50752.98	0.94	0.775

C. RESERVOIR LEVEL PREDICTION FOR HYDROELECTRIC GENERATION (F_3)

The Hydro power generation, is a function of water discharge rate and storage volume [12]. If electricity in the market is mainly produced by using hydropower systems, then the rainfalls affect the electricity price because water reservoirs can be understood as energy stocks. For instance, the lack of water increases the electricity spot price and the future prices of electricity future contracts. During dry seasons, electricity production would be low but the electricity price would be high, and during wet periods, the production would be high but the price low [6].

$$F_3 = \frac{\text{Quantity of Hydro Scheduled Power} - \text{Quantity of Hydro Unscheduled Power}}{\text{Quantity of Hydro Scheduled Power}} * W_3$$

Here W_3 is multiplying factor for the hydro power. Total Hydro power generated in India is 9% of total generated power as on 31-03-2014 and W_3=0.09*(100-3%).

Table- 6 For Calculation of factor F_3

Sr. no	Hydro based power(MU)	Unscheduled hydro power(MU)		$\frac{Q_{hsp} - Q_{husp}}{Q_{hsp}}$	F_3
		In %	In calculated form		
1	89564	3	2686.92	0.97	0.085
2	89564	5	4478.2	0.95	0.083
3	89564	6	5373.84	0.94	0.082
4	89564	7	6269.48	0.93	0.081
5	89564	8	7165.12	0.92	0.080
6	89564	10	8956.4	0.9	0.079
7	89564	9	8060.76	0.91	0.079
8	89564	4	3582.56	0.96	0.084

D. WIND POWER PREDICTION FOR WIND ELECTRIC GENERATION (F_4)

The Wind Power generation is dependent on wind speeds, its direction and weather condition forecasting wind generators output is relatively different compare to conventional generators resulting in untamed, unmanageable, irregular suppliers [7]. Total Wind Power generated in India as on 31-03-2014 is 2.5% of total power generated. Here W_4 is calculated as 0.025*(100-3%).

$$F_4 = \frac{Q_{awp} - Q_{fp}}{Q_{awp}} * W_4$$

Here Q_{awp} = Actual wind power and

Q_{fp} = Forecasted wind power

Table- 7 For calculation of factor F_4

Sr.no.	$Q_{awp(MU)}$	Forecasted factor(a)	$Q_{fp} = a*Q_{awp}$	$\frac{Q_{awp} - Q_{fp}}{Q_{awp}}$	F_4
1	24879	.68	16917.72	.32	0.008
2	24879	.78	19405.72	.22	0.005
3	24879	.74	18410.46	.26	0.006
4	24879	.76	18908.04	.24	0.006
5	24879	.80	19503.20	.20	0.005
6	24879	.72	17912.88	.28	0.007
7	24879	.70	17415.30	.30	0.007
8	24879	.66	16420.14	.34	0.008

$$PMTI(\tau) = \frac{1}{MCP\ Index} * W_{mcp} + \frac{Q_{csp} - Q_{ucsp}}{Q_{csp}} * W_2 + \frac{Q_{hsp} - Q_{husp}}{Q_{hsp}} * W_3 + \frac{Q_{awp} - Q_{fp}}{Q_{awp}} * W_4$$

MCP Index (Ip_{mc}) = $\frac{p_{mci}}{p_{mcavg}}$

p_{mci} is the MCP forith case. i=1, 2, 3…n

pmcavg = $\frac{i}{n}$ for a Demand 200MW

$$p_{mcavg} = \frac{10.4748+7.0249+5.9755}{3} = 7.8251$$

MCP Index for 5 bidders= $\frac{10.4748}{7.8251} = 1.3372$

$\frac{1}{MCP\ Index}$ For 5 bidders = $\frac{1}{1.3372} = 0.7478$

MCP Index for 7 bidders= $\frac{7.0249}{7.8251} = 0.8968$

$\frac{1}{MCP\ Index}$ for 7 bidders = $\frac{1}{0.8968} = 1.1150$

MCP Index for 10 bidders = $\frac{5.9755}{7.8251} = 0.7628$

$\frac{1}{MCP\ Index}$ for 10 bidders = $\frac{1}{0.7628} = 1.3109$

Fig.2 shows the supply side bidding curves for10 generators. Fig.3 and 4 shows the curves for double side bidding i.e. demad side and supply side bidding curves for 10 generators and 10 consumers. Table-6 shows MCP with variable demand during the day in eight Quarters (3 hours each).

Table No-8 PMT Index during eight Quarters (3 hours each) for different bidders

Time interval (quarter) 1quarter =3 hours	Unscheduled coal power	Unscheduled hydro power	$\frac{Q_{csp} - Q_{ucsp}}{Q_{csp}}$	$\frac{Q_{hsp} - Q_{husp}}{Q_{hsp}}$	$\frac{Q_{awp} - Q_{fp}}{Q_{awp}}$	PMT Index for 5 bidders here f1=0.022	PMT Index for 7 bidders here f1=0.033	PMT Index for 10 bidders here f1=0.039
1	5%	3%	0.95	0.97	0.32	0.898	0.909	0.915
2	7%	5%	0.93	0.95	0.22	0.877	0.888	0.894
3	8%	6%	0.92	0.94	0.26	0.869	0.880	0.886
4	9%	7%	0.91	0.93	0.24	0.859	0.870	0.876
5	10%	8%	0.9	0.92	0.20	0.849	0.860	0.866
6	12%	10%	0.88	0.9	0.28	0.834	0.845	0.851
7	11%	9%	0.89	0.91	0.30	0.842	0.853	0.859
8	6%	4%	0.94	0.96	0.34	0.889	0.900	0.906

Table No-9 PMTI for different bidders with change in unscheduled power (1% to 3%) for 8th quarters

Time interval (quarter) 1 quarter= 3hours	Unscheduled coal power	Unscheduled hydro power	PMT Index for 5 bidders here f1=0.022	PMT Index for 7 bidders here f1=0.033	PMT Index for 10 bidders here f1=0.039
1	3%	2%	0.916	0.927	0.933
2	5%	4%	0.894	0.905	0.911
3	6%	5%	0.886	0.897	0.903
4	7%	6%	0.877	0.888	0.894
5	8%	7%	0.867	0.878	0.884
6	9%	8%	0.859	0.870	0.876
7	8%	7%	0.869	0.880	0.886
8	3%	2%	0.916	0.927	0.933

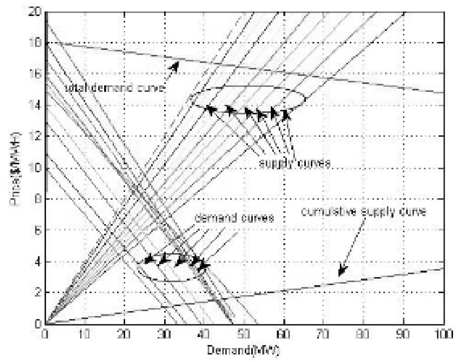

Fig.2 Combined demand and supply bid curves

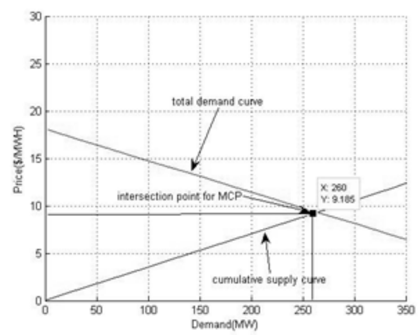

Fig. 3 Aggregate demand and supply curve: at 260 MW MCP is 9.185

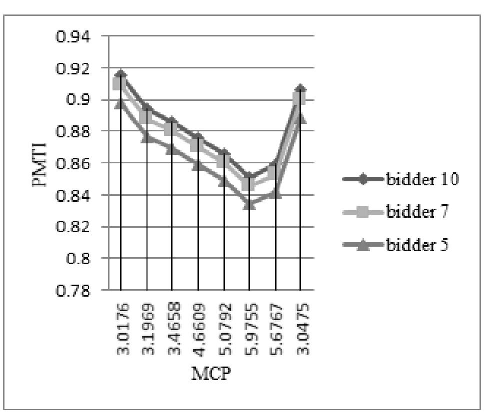

Fig. 4 Curve between MCP and PMTI for 5, 7 and 10 bidders

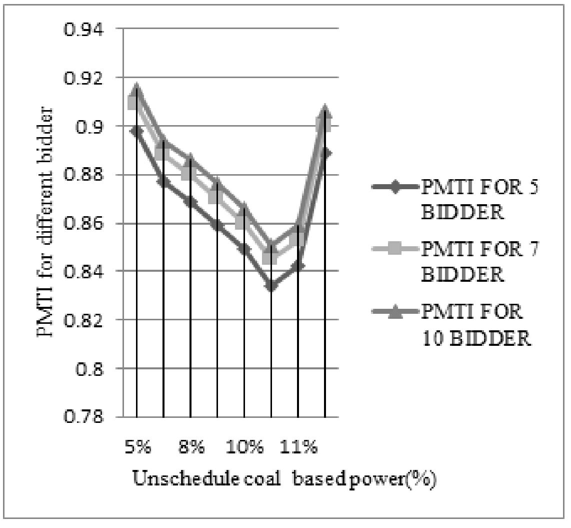

Fig.5 Curve between unscheduled coal based power (%) and PMTI for different bidder

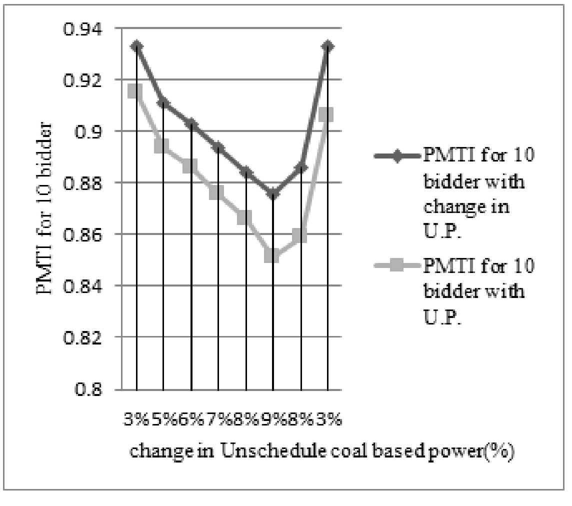

Fig.6 Curve between change in unscheduled coal based power (%) and PMTI for 10 bidder

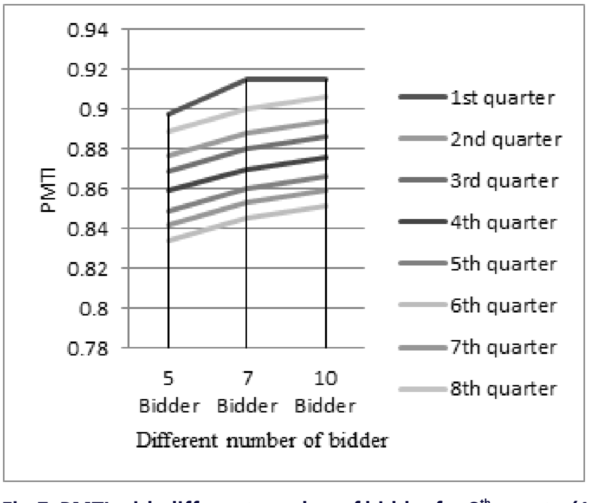

Fig.7 PMTI with different number of bidder for 8th quarter(1 quarter=3 hours)

V. RESULT AND DISCUSSION

The demand varies during the day i.e. 24 hour and accordingly MCP also varies. Table 1 shows the slope of supply curve for three cases of 5 bidders, 7 bidders and 10 bidders respectively and table 2 shows the slope of demand curve for 10 consumers. Table 3 and 4 shows that MCP is increasing as the number of bidder is decreasing and vice-versa. Fig. 2 and 3 shows the double side bidding curves i.e. supply side bidding and demand side bidding. Fig. 4 shows the curve between MCP and PMTI for 5, 7 and 10 bidder. As the MCP increases for the variable demand the PMTI decreases and vice versa as shown in Fig.4. Fig.5 shows a curve between unscheduled coals based power and PMTI for the different bidder. As the number of bidder increases the PMTI also increases. Fig. 6 shows a curve between in unscheduled coal based power (table 8) and change in unscheduled coal based power (table 9) with PMTI for 10 bidders and it can be analyzed from above result that as unscheduled power reduces the PMTI increases. Fig.7 shows the PMTI with different number of bidders.

VI. CONCLUSION

In this paper a new term Power Market Transparency Index (PMTI) for different bidders has been formulated. Higher value of PMTI shows more market transparency. Higher PMTI is also an indicator of lower unscheduled power, better information sharing of reservoir level prediction, meteorological prediction and data, climatic conditions, generation capacity availability etc.; with the interested parties. PMTI can be a tool for determining market transparency and a level playing field in a countries power market. In a power market most of the investment is done by financial institutional inform of debt. PMTI can be a tool used by Investor, financial Institutional, banks etc. in deciding the investment destination for reducing their risk. Lower the PMTI higher will be the risk of investment and vice-versa.

References

[1] P. Bajpai and S. N. Singh, "An Electric Power Trading Model for Indian Electricity Market" Power Engineering Society General Meeting, IEEE 2006.
[2] P. Bajpai and S. N. Singh, "Electricity Trading In Competitive Power Market: An Overview And Key Issues" International Conference on Power Systems, pp 110, ICPS 2004, Kathmandu, Nepal
[3] A. Badri and M. Rashidinejad, " Security constrained optimal bidding strategy of GenCos in day ahead oligopolistic power markets: a Cournot-based model", Berlin,Germany:Springer-Verlag, March 2012 .
[4] A.K.Basu, T.K.Panigrahi, S.Chowdhury, S.P.Chowdhury, N.Chakraborty, A.Sinha and Y.H.Song, "Key Energy Management Issues of Setting Market Clearing Price (MCP) in MICRO-GRID Scenario", IEEE 2008.
[5] Jussi Keppo, "Optimality With Hydropower System", IEEE Trans. on Power Systems, Vol 17, No. 3, pp. 583-589, AUGUST 2002
[6] S. N. Singh and I. Erlich, "Strategies for Wind Power Trading in Competitive Electricity Markets" IEEE Transactions on Energy Conversion, Vol. 23, No. 1, pages 249-256, March 2008.
[7] S. N. Singh and I. Erlich, "Wind Power Trading Options in Competitive Electricity Market" Power Engineering Society General Meeting, IEEE 2006.
[8] Satish kumar and R.Naresh, "Efficient real coded genetic algorithm to solve the non-convex hydrothermal scheduling problem", electrical power and energy system 29 (2007) 738-747.
[9] Yongqiang Wang , Jianzhong Zhou , Li Mo, Rui Zhang and Yongchuan Zhang, "Short-term hydrothermal generation scheduling using differential real-coded quantum-inspired evolutionary algorithm" energy, 44 2012 657-671.
[10] Vimal Singh Bisht , Gautam Shah, Nikhil Kushwaha, "Vaibhav Gupta Genetic Algorithm Solution for A Convex Hydro-Thermal Generation scheduling", 2012 Fourth International Conference on Computational Intelligence and Communication Networks.
[11] Jorge L. Angarita , Julio Usaolab and Jorge Martínez-Crespob, "Combined hydro-wind generation bids in a pool-based electricity market", Electric Power Systems Research 79 (2009) 1038–1046.
[12] Satish Kumar ,Rohit Verma and R. Pawar ,"Wind Power Trading with Block demand and linear supply in Deregulated Electricity Market", power Indian Conference 2012 IEEE Fifth,2012,pp1-6.
[13] Saroha and Verma, "cross border power trading model for south Asian regional power pool ", electrical power and energy system 44(2013) 146-152.
[14] Liu Dun-nan, Wu ya-guang, "Key Performance Indices to Monitor Bidding Behaviors in Electricity Market", Power System Conference and Exposition, 2006 IEEE PES,pp 1156-1161.
[15] Sumit Saroha and Rohit Verma, "Cross-border power trading model for south Asian regional power pool", Electrical Power and Energy Systems, 44(2013) 146-152.
[16] Global Power Markets by Dr. Rohit Verma, NPTI Faridabad (Haryana).
[17] Power line magazine (India) - volume 19 no.11 may 2011.
[18] Power line magazine (India) - volume 18 no.5 January 2014
[19] Power line magazine (India) - volume 18 no.10 June 2014
[20] NORDPOOL-The Nordic Power Exchange, http.//www.nordel.org.
[21] Electricity Market,en.wikipedia.org.in/wiki/Electricity Market.
[22] Load Generation balance Report 2014-15 , Central Electricity Authority (India).