ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

Bidding based power flow in restructured power market

J.Mekala, Dr. R. Gnanadass
Dept.of Instrumentation& Control Engg, A.D.J. Dharmambal polytechnic college, Nagapattinam
Dept. of Electrical & Electronics Engg, Pondicherry Engineering College, Pondicherry

***Abstract*— Auction serves as a primary pricing tool in various market segments of a deregulated power industry such as day ahead market, real time market, ancillary services market, and financial transmission rights (FTR) market. Deregulated power markets around the world use different auction strategies, since very little comparative guidelines exist as to the relative merits of these strategies. The main objective of the project is to determine power flow using bidding strategy. In this project the bidding structure of the generator is taken in blocks as in real competitive power market. The market clearing price is obtained from the load demand of the system. The generation schedule is adjusted as per the market clearing price and load flow program is run for the generator settings.**

Keywords— **deregulated power market, bidding, supply, demand, market clearing price.**

I. INTRODUCTION

For most of the twentieth century, when consumers wanted to buy electrical energy, they had no choice. They had to buy it from the utility that held the monopoly for the supply of electricity in the area where these consumers were located. Some of these utilities were vertically integrated, which means that they generated the electrical energy, transmitted it from the power plants to the load centers and distributed it to individual consumers. In other cases, the utility from which consumers purchased electricity was responsible only for its sale and distribution in a local area. This distribution utility in turn had to purchase electrical energy from a generation and transmission utility that had a monopoly over a wider geographical area. In some parts of the world, these utilities were regulated private companies, while in others they were public companies or government agencies. Irrespective of ownership and the level of vertical integration, geographical monopolies were the norm.

Electric utilities operating under this model made truly remarkable contributions to economic activity and quality of life. Most people living in the industrialized world have access to an electricity distribution network. For several decades, the amount of energy delivered by these networks doubled about every eight years. At the same time, advances in engineering improved the reliability of the electricity supply to the point that in many parts of the world the average consumer is deprived of electricity for less than two minutes per year. These achievements were made possible by ceaseless technological advances. Among these, let us mention only the development and erection of transmission lines operating at over 1 000 000 V and spanning thousands of kilometers, the construction of power plants capable of generating more than 1000 MW and the online control of the networks connecting these plants to the consumers through these lines.

In the 1980s, some economists started arguing that this model had run its course. They said that the monopoly status of the electric utilities removed the incentive to operate efficiently and encouraged unnecessary investments. They also argued that the cost of the mistakes that private utilities made should not be passed on to the consumers.

These economists suggested that prices would be lower and that the economy as a whole would benefit if the supply of electricity became the object of market discipline rather than monopoly regulation or government policy. This proposal was made in the context of a general deregulation of western economies that had started in the late seventies. Before attention turned toward electricity, this movement had already affected airlines, transportation and the supply of gas. In all these sectors, regulated market or monopolies had been deemed the most efficient mean of delivering the "products" to the consumers. It was felt that their special characteristics made them unsuitable for trading on free markets. Advocates of deregulation argued that the special characteristics of these products were not insurmountable obstacles and that they could and should be treated like all other commodities. If companies were allowed to compete freely for the provision of electricity, the efficiency gains arising from this competition would ultimately benefit the consumers. In addition, competing companies would probably choose different technologies. It was therefore less likely that the consumers would be saddled with the

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018
consequences of unwise investments to the government. Politics could then interfere with good economics.

For example, some if electricity truly were a simple commodity kilowatt-hours could be stacked on a shelf – like kilograms of flour or television sets – ready to be used as soon as the consumer turns on the light or starts the industrial process. Despite recent technological advances in electricity storage and micro generation, this concept is not yet technically or commercially feasible. The reliable and continuous delivery of significant amounts of electrical energy still requires large generating plants connected to the consumer through transmission and distribution networks.

II. FUNDAMENTALS OF MARKET

Markets are a very old invention that can be found in most civilizations. Over the years, they have evolved from being simply a location where a few people would occasionally gather to barter goods to virtual environments where information circulates electronically and deals are made with a click of a mouse. Despite these technological changes, the fundamental principle has not changed: a market is a place where buyers and sellers meet to see if deals can be made. To explain how markets function, we will first develop a model that describes the behavior of the consumers. Then, we will develop a model explaining the activities of the producers. By combining these two models, we will be able to show under what conditions deals can be struck.

DEMAND AND INVERSE DEMAND FUNCTIONS

It is very unlikely that all the consumers going to the market have exactly the same appetite for apples as you do. Some of them would pay much more for the same number of apples, while others buy apples only when they are cheap. If we aggregate the demand characteristics of a sufficiently large number of consumers, the discontinuities introduced by the individual decisions are smoothed away, leading to a curve like the one shown in Figure 2. This curve represents the *inverse demand function* of the customers taken as a whole. If q represents the quantity consumed and π the price of the commodity, we can write

$\pi = D^{-1}(q)$ ------ Eqn(1)

If we look at the same curve from the other direction, we have the *demand function* for this commodity: $q = D(\pi)$ ------ Eqn (2)

MARKET CLEARING PRICE

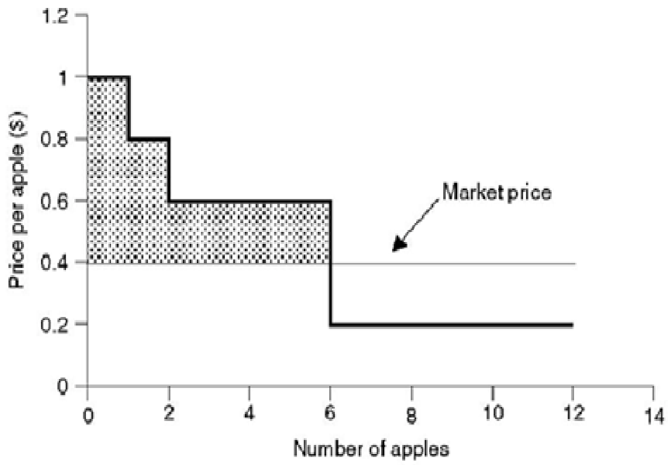

Fig . 1 Net consumer's surplus resulting from the purchase of apples

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

PRICE Vs QUANTITY

Fig.2 Price Vs quantity curve

For most, if not all, practical commodities, the demand function is downward sloping, that is, the amount consumed decreases as the price increases. The inverse demand function has an important economic interpretation. For a given consumption level, it measures how much money the consumers would be willing to pay to have a small additional amount of the good considered. Turning this around, it also tells how much money these same consumers would want to receive in compensation for a reduced consumption. Not spending this amount of money on this commodity would allow them to purchase more of another commodity or save it for purchasing something at a later date. In other words, the demand curve gives the *marginal value* that consumers attach to the commodity.

The typical downward-sloping shape of the curve indicates that consumers are usually willing to pay more for additional quantities of a commodity when they have only a small amount of this commodity. Their marginal willingness to pay for this commodity decreases as their consumption increases. The net surplus corresponds to the area between the inverse demand function and the horizontal line at the market price.

TYPICAL SUPPLY CURVE

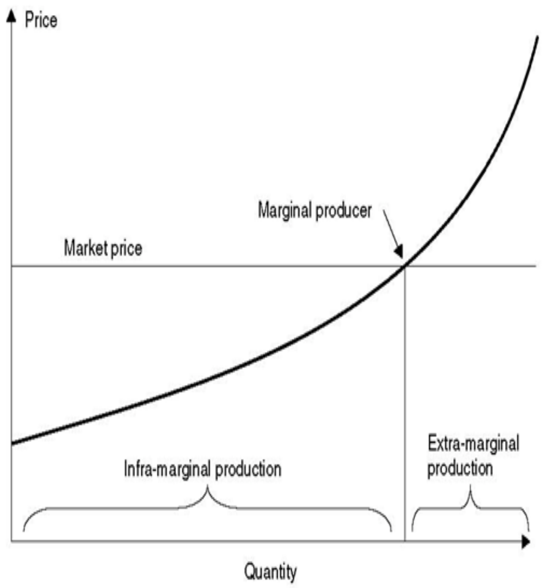

Fig 3. Marginal production is such that its opportunity cost is equal to the market price

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

III. PROBLEM FORMULATION

In the restructured power market there are two main entities participating in the market. i.e customer and producer. The pool operator takes electricity transaction bids and offers from these two entities and dispatches them in an economic manner depending on the price and MW biddings. In general the customers and power producers do not directly interact to each other, but only indirectly through the pool operator. After all bids and offers have been received an optimization tool will be used to solve the problems which includes loss allocation, congestion management and other ancillary services.

In the pool market model if the demand is in elastic to the price, the social welfare maximization will concern only the supplier benefit receiving from the electricity sold in the market. Traditional system operating cost in the OPF formulation will be substituted by the product of supply offered prices and MW quantities, i.e, the area under the supply curve as shown in figure 4.

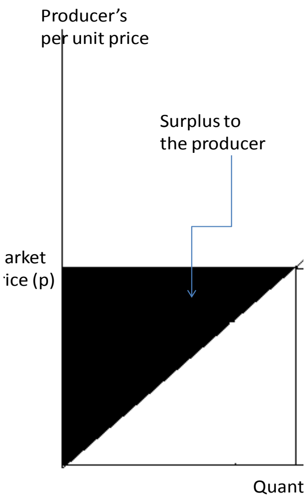

Fig 4. Surplus to the producer

Surplus to the producer = $\int_0^q (p - S(q))dq$.

In pool market, with demand elasticity customer benefit represents the value which the customers gain from using electricity. The surplus to the consumer is the area between the market clearing price and consumer willingness to buy which is shown in the figure 5.

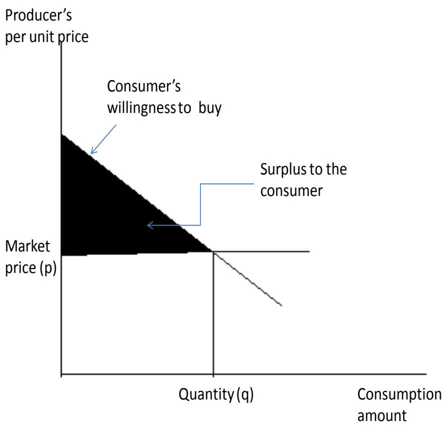

Fig 5. Surplus to the consumer

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

Surplus to the consumer = $\int_0^q (D(q) - p)dq$

The main objective of the ISO is to minimize the cost of suppliers and to maximize the customer benefit. Graphically as shown in figure 6, it is to maximize the area bound by the demand and supply curves for which the optimization problem can be set up in the form of

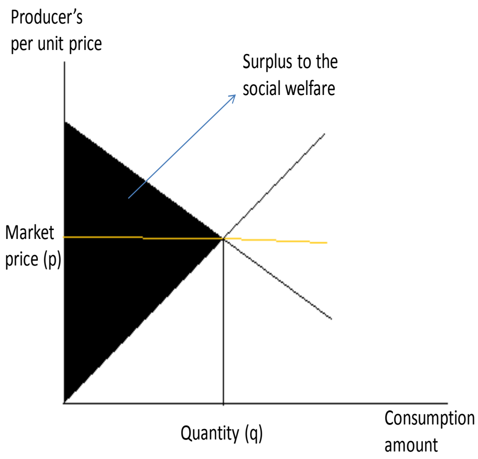

Fig 6. Surplus to social welfare

Total surplus to social or social welfare = surplus to consumer + surplus to producer

$$=\int_0^q (D(q) - S(q))dq$$

Maximization of social welfare is equivalent to the minimization of

$$=\int_0^q (S(q) - D(q))dq - \sum S(q) - \sum D(q)$$

MARKET CLEARING PRICE

Power on the spot market is traded on hourly basis. Before the start of each hour generators enter bids specifying the quantity of power they are offering and the price they are demanding. A generator may divide the power it intends to sell in to many smaller bids, so that it can effectively offer a bid curve which reflects its marginal cost. The predicted spot market demand is generally estimated by the spot market co-ordinator. Once a spot market demand has been determined, the generator bids are stacked starting with the lowest price. The point at which the stack of bids intersects the cumulative load specifies the market clearing price. It is the price demanded by the most expensive bid accepted. This price will be awarded to all accepted bids. The process of determining the market clearing price is shown in figure 4.

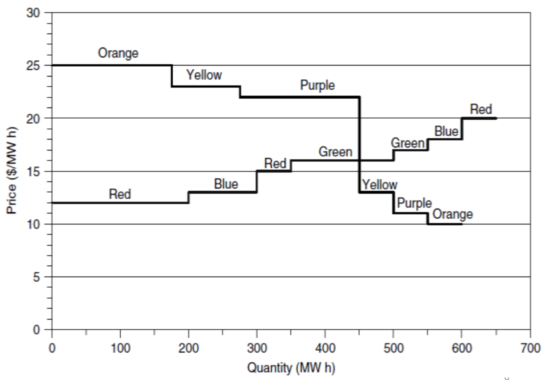

Fig 7. Bidding strategy

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

IV. SIMULATION RESULTS AND DISCUSSIONS

CASE STUDY 1.1: FOUR BUS SYSTEM

The four bus system contains 2 Generators, 5 transmission lines and 2 loads.

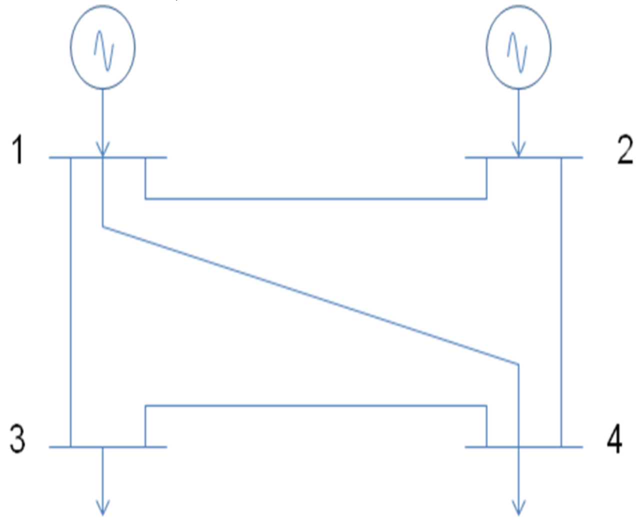

Fig 8. Four bus system

Table 1. Bids offered by generators

BIDS	UTILITY	AMOUNT In MW	PRICE In Rs/MWh
BID 1	Generator 1	50	2750
BID2		50	3000
BID3		60	3750
BID4		40	4000
BID 1	Generator 2	50	3500
BID2		50	4000
BID3		100	4500

Demand: 150MW, 250MW, 350MW

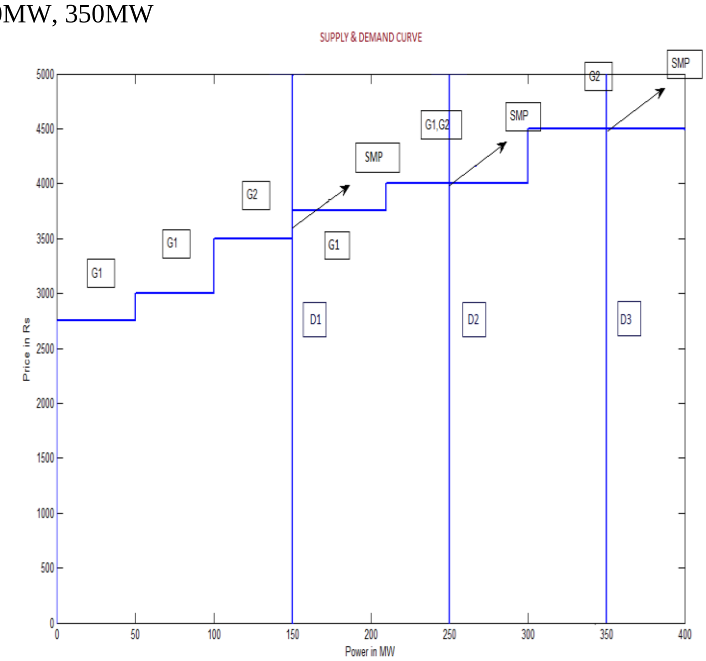

Fig 9. Supply curve for 4 bus system

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

Table 2.Generation schedule for different loads

Load in MW	Generator1 contribution in MW	Generator2 contribution in MW	SMP in Rs.	[illegible]
150	100	50	3625	[illegible]
250	[illegible]	[illegible]	4000	[illegible]
250	200	50	4000	[illegible]
350	200	150	4500	[illegible]

CASE 1.1.a ***<u>Base load of 150 MW</u>***

To meet the base load demand of 150 MW, G1 must generate 100 MW + losses and G2 must generate 50 MW. In this case G1 bids Rs 2750 / MW for the first 50 MW and Rs 3000 / MW for the next 50 MW. G2 bids Rs 3500 / MW for 50 MW. Hence, for a demand of 150 MW, the market clearing price becomes Rs 3500 / MW. However in this case, the demand line lies exactly in the transition region where the next bid of Rs 3750 / MW takes place. Hence, the market clearing price for this case taken as the average of these two prices i.e Rs 3625 / MW.

CASE 1.1.b. ***<u>Critical load of 250 MW</u>***

To meet the critical load demand of 250 MW the market clearing price is found to be Rs 4000 / MW from the supply curve. Here both generators bids for Rs 4000 / MW. Hence to find the optimum generation schedule we have to run the load flow and find the line losses .From this the generation schedule is chosen which gives minimum line loss. The optimum schedule is G1 = 160 MW + line losses and G2 = 90 MW.

CASE 1.1.c. ***<u>Peak load of 350 MW</u>***

From the supply curve the market clearing price for the demand of 350 MW is found to be Rs 4500 / MW.

<u>CASE STUDY 1.2; 26 BUS SYSTEM.</u>

The 26 bus system contains 6 Generators, 46 transmission lines and 9 VAR sources

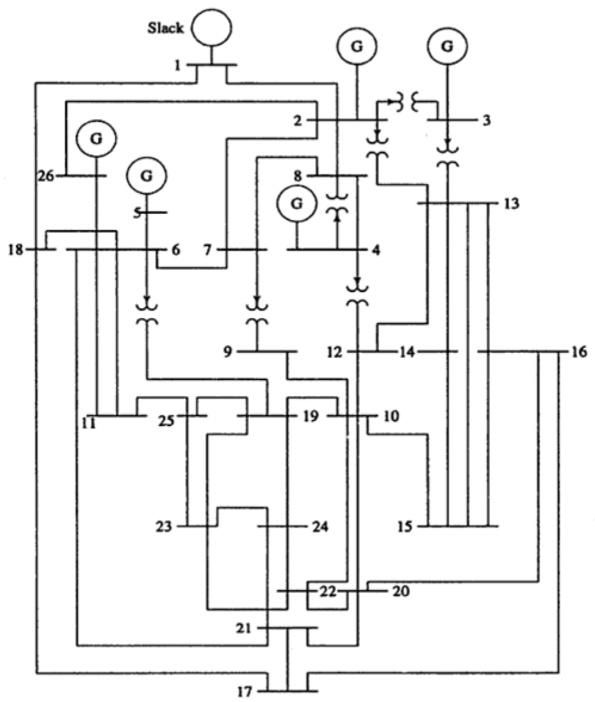

Fig 10. 26 bus system

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

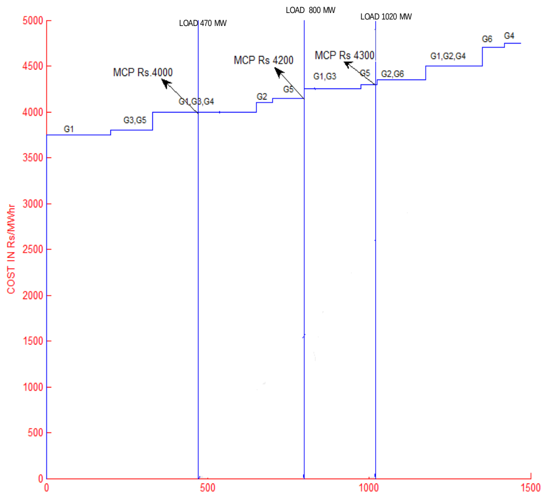

Fig.11. Supply curve for 26 bus system

Table 3. Generation schedule for 26 bus system

LOAD IN MW	G1 MW	G2 MW	G3 MW	G4 MW	G5 MW	G6 MW	MCP Rs	TOTAL LOSS IN MW	STATUS
470	234.015	-	140	50	50	-	4000	4.015	Not violates
800	356.687	50	200	50	150	-	4200	6.687	Violates
800	416.892	50	140	50	150	-	4250	6.892	Not violates
1020	435.088	50	300	50	195	-	4300	10.088	Violates
1020	379.386	150	150	100	200	50	4500	9.386	Not violates

CASE 1.2.a. Base load of 470 MW

From the supply curve the market clearing price for a base load of 470 MW is found to be Rs 4000 / MW. In this case generators G1, G3 & G4 bids for the same price. For different generation schedule the load flow program is run and the line loss is found . From this the schedule which gives minimum loss is considered as optimum. The total line loss is 4.015 MW. The optimum generation schedule for each generators on the 26 bus system is G1 = 230 MW + losses, G2 = Nil, G3 = 140 MW, G4 = 50 MW, G5 = 50 MW & G6 = Nil.

CASE 1.2.b. Critical load of 800 MW.

From this supply curve the MCP is found to be Rs 4200 / MW and the generation schedule is as follows.
G1 = 350 MW, G2 = 50 MW, G3 = 200 MW, G4 = 50 MW, G5 = 150 MW & G6 = NIL.
However when we run the load flow for this case , the transmission line limit on 3-13 violates. Hence generation schedule is altered as follows. G1 = 410 MW, G2 = 50 MW, G3 = 140 MW
G4 = 50 MW, G5 = 150 MW & G6 = NIL. Now the MCP is raised to Rs 4250 / MW.

CASE 1.2.c. Peak load of 1020 MW.

For a peak load demand of 1020 MW the MCP is found to be Rs 4300 / MW from the supply curve and the generation schedule is
G1 = 425 MW , G2 = 50 MW , G3 = 300 MW

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

G4 = 50 MW, G5 = 195 MW & G6 = NIL.
However the transmission line limits are violated and the line losses are very high. Hence the generation schedule is altered and MCP is changed to be Rs 4500 / MW. Total line loss is 9.386 MW.

CASE STUDY 2. DAILY LOAD CURVE.

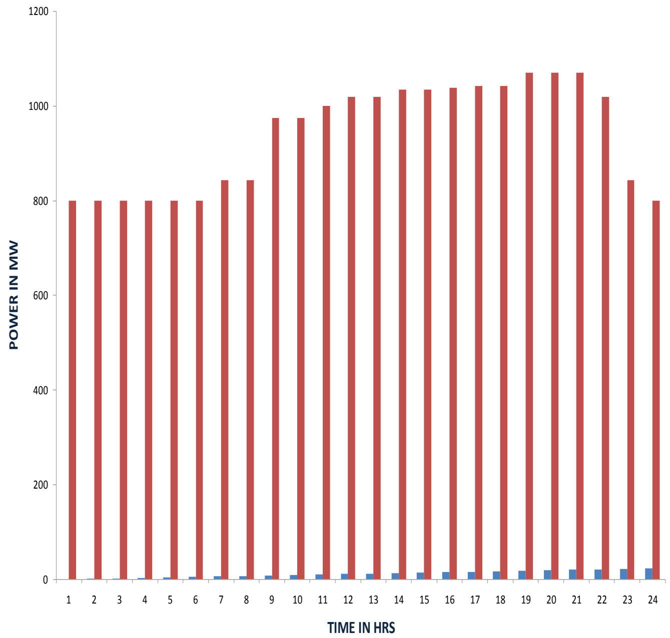

Fig.12. Daily load curve

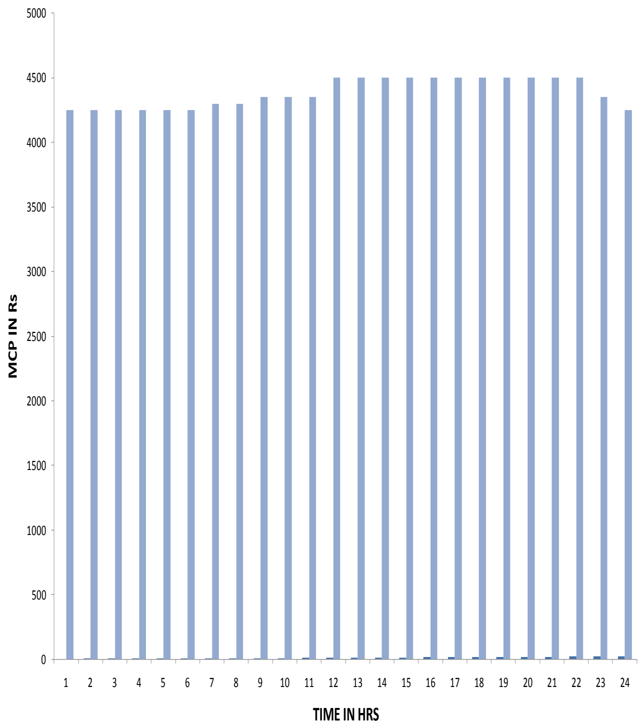

Fig.13. Market clearing price for 24 hours

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 7, Issue 6, November 2018

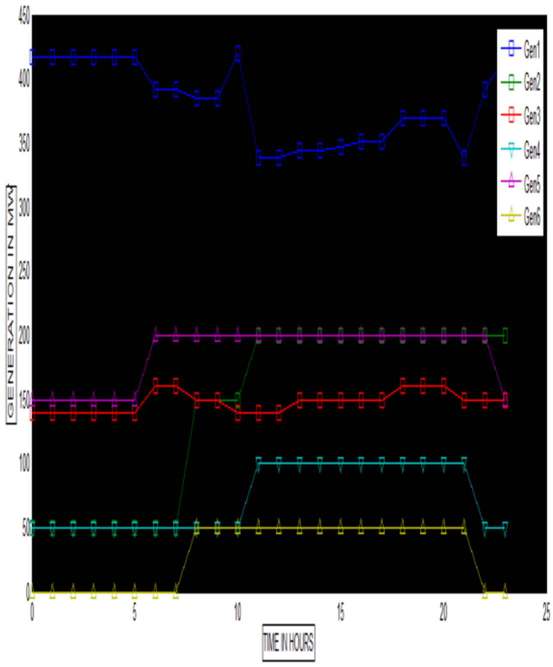

Fig 14. Hourly generation

V. CONCLUSION

In this paper the power flow analysis for four bus system and twenty six bus Indian utility systems are carried out using Newton Raphson method The Generator settings are obtained from bidding blocks and the same is incorporated on four bus and twenty six bus practical system. The power flow is carried out using the above generator settings and the corresponding MCP is obtained. While incorporating power flow, the line flow constraints are included. The bidding analysis is carried for Base load, High load & Critical load. The generator settings during the critical load conditions are taken with respect to the magnitude of line losses obtained in the system.

REFERENCES

[1] Hongye Wang, Carlos E.Murillo-Sanchez, Ray D. Zimmerman & Robert J. Thomas "On Computational Issues of Market- Based Optimal Power flow"- IEEE Transactions on Power systems, vol.22,No.3, August 2007,pp.1185-1192.

[2] H.F.Illian, Member IEEE,"Optimal Power Flow in a Market"- 1999, IEEE', pp.1066-1067.

[3] Taiyou Yong, Robert Lassetor, 'Optimal Power Flow Formulation in Market of Retail Wheeling'-Pserc 99-03.

[4] Javier Contreras, , Oscar Candiles, José Ignacio de la Fuente, and Tomás Gómez," A Cobweb Bidding Model for Competitive Electricity Markets" IEEE Transactions on Power Systems, VOL. 17, NO. 1, February 2002, pp. 148-153.

[5] Reinaldo C. Garcia, Javier Contreras, Marco van Akkeren, and João Batista C. Garcia," A GARCH Forecasting Model to Predict Day-Ahead Electricity Prices" IEEE Transactions on Power Systems, VOL. 20, NO. 2, May 2005, pp. 867-874.

[6] Vishnuteja Nanduri and Tapas K. Das," A Methodology for Evaluating Auction Based Pricing Strategies in Deregulated Energy Markets" Department of Industrial & Management Systems Engineering ,University of South Florida, Tampa, Florida 33620,pp 1-12.

[7] Vishnuteja Nanduri, and Tapas K. Das, "A Reinforcement Learning Model to Assess Market Power Under Auction-Based Energy Pricing" IEEE Transactions on Power Systems, Vol. 22, No. 1, February 2007, pp 85-95.

[8] Miguel Carrión, Andy B. Philpott, Antonio J. Conejo, and José M. Arroyo, " A Stochastic Programming Approach to Electric Energy Procurement for Large Consumers", IEEE Transactions on Power Systems, Vol. 22, No. 2, May 2007, pp 744-754.

[9] Robert Ethier, Ray Zimmerman, Timothy Mount, William Schulze, Robert Thomas," Auction Design for Competitive Electricity Markets", HICSS Conference January 7-10, 1997 Maui, Hawaii, pp 1-19.

[10] Javier Contreras, Oscar Candiles, José Ignacio de la Fuente, and Tomás Gómez, "Auction Design in Day-Ahead Electricity Markets", IEEE Transactions on Power Systems, Vol. 16,No. 3, August 2001, pp 409-417.

[11] Francisco J. Nogales, Javier Contreras, Antonio J. Conejo, and Rosario Espínola," Forecasting Next-Day Electricity Prices by Time Series Models"IEEE Transactions on Power Systems, Vol. 17, No. 2, May 2002, pp342-348.

[12] Francisco D. Galiana, Antonio J. Conejo, and Ivana Kockar," Incremental Transmission Loss Allocation Under Pool Dispatch" IEEE Transactions on Power Systems, Vol. 17, No. 1, February 2002,pp 26-33.

[13] Kwok W. Cheung, Senior Member, IEEE, Payman Shamsollahi, Member, IEEE, David Sun, Member, IEEE, James Milligan, and Mike Potishnak," Energy and Ancillary Service Dispatch for the Interim ISO New England Electricity Market" IEEE Transactions on Power systems, vol. 15, No. 3,August 2000,pp 968-974.

[14] Francisco J. Nogales, Javier Contreras, Member, IEEE, Antonio J. Conejo, Senior Member, IEEE, and Rosario Espínola," Forecasting Next-Day Electricity Prices by Time Series Models" IEEE Transactions on Power systems, vol. 17, No.2, May 2002, pp342- 348.