Pay-As-Bid versus Uniform Pricing Mechanism in Restructured Power Systems

Mohammad Sadegh Javadi[1], Amin Javadinasab[2]

[1.] Department of Electrical and Electronic Engineering, Islamic Azad University, Science and Research Branch, 73715-181, Fars, Marvdasht, Iran
[2.] Islamic Azad University, Shoushtar Branch, Shoushtar, Iran
msjavadi@gmail.com

Abstract: Energy markets have specifically different mechanism in quite varying countries. Even in one country, it might be that mechanism of electrical market is different from each other. What is similar in this markets is satisfying load or demand as a main target. In the worldwide electricity markets, ordinary mechanism of market clearing implied as a uniform price, while mechanism of payment in Iran's electricity market based on the model of pay-as-bid by energy generation companies. This paper is surveying these two mechanisms and introducing its weak and strong points.
[Mohammad Sadegh Javadi, Amin Javadinasab, Pay-As-Bid versus Uniform Pricing Mechanism in Restructured Power Systems Journal of American Science 2011;7(3):438-443]. (ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Generation Expansion Planning (GEP), Load Duration Curve (LDC), Pay-as-Bid (PAB) mechanism, Uniform Payment (UP) mechanism

1. Introduction

Before restructuring in electricity industry, the structure of generation, transmission, distribution and operation from network was known as a vertically integrated chain. In this situation, government with public service provider had duty to supply energy in the cheapest way for the generation cost from end users and would be paid to all producers (R. Green, 1999). In supply side, this received expenses will spend on crew cost, fuel cost, Variable Operation and Maintenance (VOM) cost, loss, Infrastructure expansion planning. Therefore, total of the receipts and payments manage integrated in these systems (Shrestha et al., 2001). This management and operation of power systems, named as vertically integrated too, because this chain of generation, transmission and distribution manage entirely. In this area, practically there is not any difference between units with high efficient and the low one. Successful privatization experiences in various industries such as communication and transportation and airlines in many countries due to put the energy supplying chain into prospective in order to enter in a competitive market. In result, the process of privatization of electricity Industry has begun. With intention to the topic competition and accounting arguments and their focus on these chains, in each of these countries demonstrated specific regulation for considering this issue (Kirschen and Strbac, 2004).

The main goal in restructuring in restructure in electricity industry is decentralization from government sector into private one, developing competition, and increasing long term efficiency and most important of all long term social welfare. It is to note that regulation approved with this goal (Shahidehpour, et al. 2002). Due to lack of motivation for generation companies with low efficiency for improving their generation and their technologies and increasing the unit efficiency, operation of conventional generation units is very least efficient. In this case, cost based model obtained from generation level and their supplementary imposed costs. In fact, cost function is proposed by generation level. This cost function shows that the cost of energy production corresponding with generating level. Finally, this cost will be aggregate and segregate correspondingly with the demands (Bhattacharya et al., 2001). In restructured competitive power market, the condition is vice-versa of this case. In the other words, the conditions are similar to other economic systems based on offer and demand, the amount of tendency of Genco's for each level of generating level determined and offered to market. Consequently, the high efficiency unit has more tendencies to generation for a specific price than a low efficiency unit does. So electricity market will manage similar to an economic-management system. In this case, units should offer their capability for supplying the energy (Javadi and Monsef, 2008).

2. Operation of Generation Units in Vertically Integrated Power Systems

In conventional power system, at first, load forecasting for generation scheduling and the amount of energy demand estimated for next 24 hours (It means the day-ahead load forecasting). In

the second order of merit, economic dispatch of supplying the load is carried out. In this case, demands have a price elasticity of zero and considered as a solely constraint. In this case decision-making attributes is marginal cost of generation units. In other words, the units that selected for generation should have lesser cost of generation than marginal cost or the generation cost of them should be equal with marginal cost. From point of view of economy, marginal cost has profound concepts that can search these concepts in economical documents. In this model, the marginal cost will defined via the amount of load.

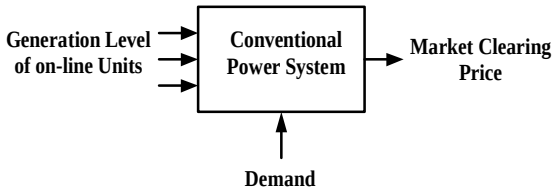

Figure .1 Operation model of conventional power system

3. Operation of Generation Units in Restructured Power Systems

In modern power system, the condition is vice-versa of above case. In the other words, generation would offer their marginal cost of generation units under operation in the first step. Optimum generation level will be distinct by these offers. In this regard, customer desire about maintaining the demands will be receive. Market Clearing Price (MCP) will be reached by crossing of aggregated supply curve and aggregated demand curve. Because of particular properties of electricity commodity, the price elasticity is extremely low (Javadi et al., 2009). In this paper, due to have simple analysis, loads are non-elastic. In the following section different PAB mechanisms will present.

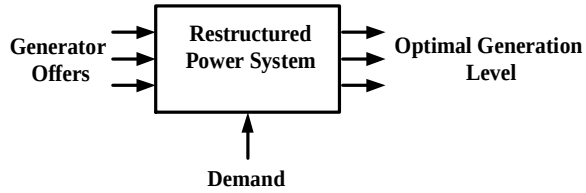

Figure.2 operation model of modern power system

3.1. Pay-As Bid versus uniform pricing Mechanism

There are two mechanisms after settling the market and defining the MCP, for pay to generation units. One of them is Pay-as-Bid (PAB) and another one is Uniform Pricing (UP). In PAB mechanism, each of the generation companies (Genco's) that are in generation scheduling will be paid based on its offer bid. In UP mechanism, all of the Genco's that are in generation scheduling received the price of settling the market after defining the MCP and determining the most expensive generation unit (that will determine the final accepted price). Consequently, all of the Genco's will receive similar price. For this reason, this mechanism is uniform pricing (Bouffard et al., 2005). This article surveys the characteristics and differences between these tow mechanisms. The following simple example illustrates these characteristics and differences:

Suppose that we have two generation units (A and B). Offering their desire supply function as below:

Table.1 Generation steps of unit A

Unit A	A1	A2	A3	A4	A5
Declared(MW)	0-10	10-30	30-100	100-150	150-200
Declared($/MWh)	10	20	30	35	50

Table.2 Generation steps of unit B

Unit B	B1	B2	B3	B4	B5
Declared(MW)	0-20	20-40	40-60	60-90	90-120
Declared($/MWh)	15	22	25	40	45

If the hourly load demand is as figure 3, settling the market price and payment are obtained as follows:

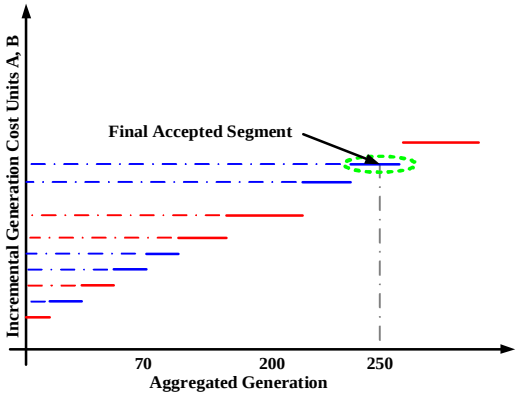

Figure 3. (a) Mechanism of market based on PAB

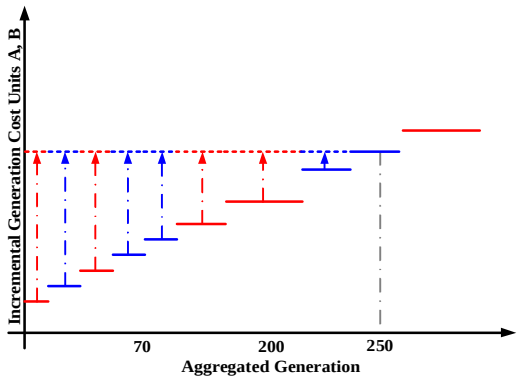

Figure 3. (b) Mechanism of market based on UP

Suppose that three generating technology A, B and C are available which should supply the load at any moment. A is a 400 MW unit, B is a 500 MW unit and the capacity of unit C is 120 MW. Figure 4 shows the load duration curve (LDC).

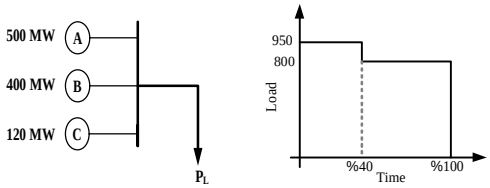

Figure 4. LDC of studied example and diagram of generation system and load

Figure 4 shows that in %40 of time, load demand is 950 MW and in the remaining %60 of time, load is 800 MW. LDC is obtained from the Daily Load Curve (DLC). Through arranging the load from ascending to descending and with knowing the information of load demand for 24 hours, DLC is obtained; and with knowing the information of load demand for 8760 hours, Annually Load Duration Curve (ALDA) is attained. From point of view of economic, marginal cost is the slope of cost function. Therefore marginal costs are achieved for three different generating technologies. See figure 5.

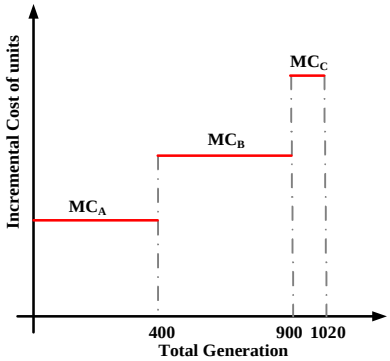

Figure 5(a). Increasing marginal cost curve

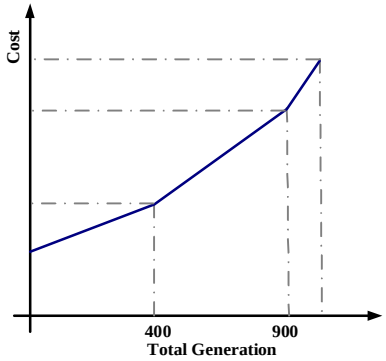

Figure 5. (b) Comparative cost curve

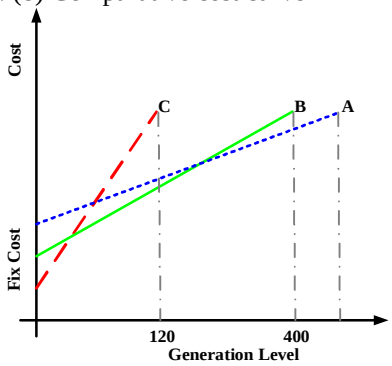

Figure 5(c). Cost model of generation units

3.2 Pay-as-Bid mechanism and profit calculation

Profit is calculated by taking the revenue and costs. The difference between cost and revenue is profit of entity. Accordingly, profit is computed as follows:

Assume that the generations cost for each unit is marginal cost. So for each unit, the cost of generation is consists of fix and variable cost proportional with amount of generation that its mathematical expression is a first-order linear function as follows:

$$Cost_i = Fix_i + Var_i \times P_i \quad (1)$$

For each unit, revenue is calculated as follows:

Unit A:
This unit is cheapest so in on-line all of the time.

$$\begin{aligned} &\mathrm{Rev}_A = (0.4\times 400\times \pi_A + 0.6\times 400\times \pi_A) \\ &-(Fix_A + 400\times \pi_A) = -Fix_A \end{aligned} \quad (2)$$

Unit B:
This unit is a full load unit in %40 of the time, but in the remaining %60 of the time, the unit is on-line with 400 MW.

$$\begin{aligned}&\mathrm{Rev}_B = (0.4\times 500\pi_B + 0.6\times 400\pi_B)\\&-(Fix_B + 0.4\times 500\times\pi_B + 0.6\times 400\times\pi_B)\\&= -Fix_B\end{aligned} \quad (3)$$

Unit C:
This unit is an expensive unit. So it is on-line with 50 MW in %40 of time and it's off-line in the remaining %60 of the time.

$$\begin{aligned}&\mathrm{Rev}_C = (0.4\times 50\times\pi_C)\\&-(Fix_C + 0.4\times 50\times\pi_C)\\&= -Fix_C\end{aligned} \quad (4)$$

If all of the generation units offered their marginal costs to the market, they are lost the fix cost. The amount of their losses is equal to their fix costs. It can be shown that in this mechanism, Is not desirable for Genco's to offer their marginal cost to the market.. It is to note that Genco's presented a price that is more than the marginal cost. So it is a worry for end user. As mentioned previously, one aim of restructuring is to increase social welfare from both consumer and Genco's. In this case, there is not any tendency to energy generation in short term and there is not any positive signal for investing in generation sector in long term. Before presenting the other countries energy policy and approaches in their operation of their electricity markets, we would like to calculate the profit in uniform mechanism (Soheily, 2000).

3.3 Uniform mechanism and profit calculation

Consider the earlier example; Unit A is a full load unit; unit B is a full load unit in %40 of the time, but in the remaining %60 of time, the unit is on-line with 400 MW so this unit is a marginal unit and would be a price maker and unit C that supplies the load (50MW) in %40 of the time (at on-peak time) determines the price in this range. In this mechanism, profit calculated as;

$$\begin{aligned}&\mathrm{Rev}_A = (0.4\times 400\pi_C + 0.6\times 400\pi_B)\\&-(Fix_A + 400\pi_A)\\&= (0.4\pi_C + 0.6\pi_B - \pi_A)400 - Fix_A\end{aligned} \quad (5)$$

$$\begin{aligned}&\mathrm{Rev}_B = (0.4\times 500\pi_C + 0.6\times 400\pi_B)\\&-(Fix_B + 0.4\times 500\pi_B + 0.6\times 400\pi_B)\\&= 0.4\times 500(\pi_C - \pi_B) - Fix_B\end{aligned} \quad (6)$$

$$\begin{aligned}&\mathrm{Rev}_C = (0.4\times 50\times\pi_C)\\&-(Fix_C + 0.4\times 50\times\pi_A)\\&= -Fix_C\end{aligned} \quad (7)$$

According to the result, it is clear that only conditions for unit C are similar to the PAB mechanism. Note that, the amount of loss is less than for other units that have lesser cost or they have not any loss at all. So as a generally result and for profit, the amount of risk in bidding strategy of generation units in PAB mechanism is more than UP mechanism. In addition, rising costs seems quite reasonable in such circumstances. Suppose that there are some incentives for investing in private sector and Genco's, too.

4. Calculation of loss of load cost and market intervention

In both mechanisms, there are conditions that in them operation prices of generation units for covering fix costs are more than marginal costs of their generation. So prices will be more expensive. This case is more common in PAB mechanism.

Suppose that unit C is not generating energy. It is not delivering to network, too. Therefore, power system has e loss of load (50 MW) in %40 of the time. Ordinary the loss of load is 50-100 times of real cost of energy generation. In this case, system pays more prices because of no facing with loss of load. Assume that the system is using a virtual generator unit for making to equivalent with loss of load. So fix and quasi-fix costs for this unit are zero and variable costs are value of loss of load (VOLL using in reliability calculation of network).

Add a virtual generator unit (equal with loss of load) to previous example in UP mechanism. In this case, if the VOLL exists, there will be no more loss for each unit. For example, in unit C:

$$\begin{aligned}&\mathrm{Rev}_C = VOLL\times T_D + \pi_C(T_C - T_D)\\&-(Fix_C + \pi_C\times T_C)\end{aligned} \quad (8)$$

Finally

$$VOLL\times T_D - \pi_C T_D = Fix_C \quad (9)$$

$$\mathrm{Rev}_C = Fix_C - Fix_C = 0 \quad (10)$$

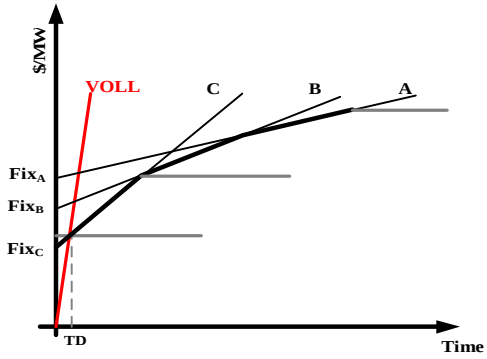

Figure 6. Comparative cost curve and the relation between VOLL and Fix_C

Consequently, there is not any loss for unit C because it accepted as last unit in market. Obviously, condition of profit is positive for other units. Capacity payment index is a product of loss of load probability (LOLP) and VOLL and defined as:

$$CP = LOLP(VOLL - SMP) \quad (11)$$

Where,
CP: Capacity Payment of unit
LOLP: Loss of Load probability
VOLL: Value of Load Loss
SMP: System Marginal Price

Units of CP are $\frac{\$}{kWh}$ and $\frac{\$}{MWh}$.

Suppose that an investor wants to install a new generation unit in TD range for supplying the load. Construction cost of On-peak load unit is identified as;

$$CCOPU = LOLP(VOLL - SMP) \quad (12)$$

In PAB mechanism; such as Iran Electricity Market, if there is tendency to CP, so there will be tendency to generation expansion planning (GEP) and augmenting the role of existing generation units. In this case, high efficiency generation companies have high profit. For that reason, there is a comparative mood for generating energy.

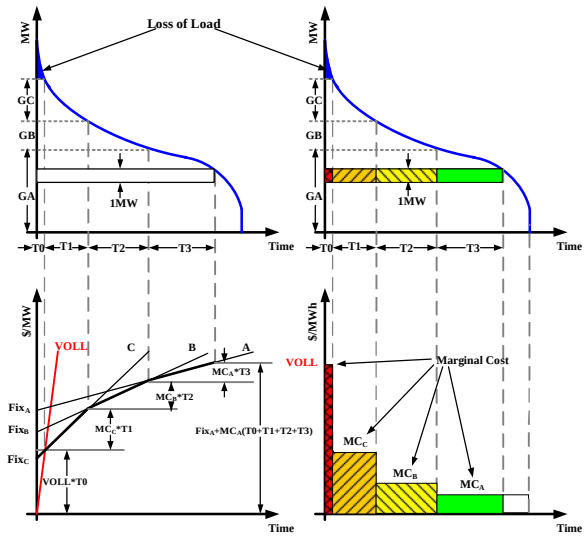

Figure 7. Cognitive model of Intermediary marketing interfering mechanism

As a unit is going to be more efficient, the possibility of being online and gaining CP in the hours of being on-line will increase. Therefore, this incentive factor creates a positive signal to improving efficiency of generation units in long-term and competition in being on-line in short-term. Genco's have tendency to present real price of generation (marginal cost of generation) in this market and comparative conditions. As a result, in this case, it can be said that CP can make a kind of balanced and rational competition between generation units because of in this condition, bidding strategy to be closer to the marginal cost.

5. Discussions

In this paper, market clearing mechanism in Electricity market and accepted mechanism in other countries in a comparative and analytical process have been carried out. Results shown that in PAB mechanism, there is increasing of offered prices by Genco's. In this area, investment analysis in GEP, investors should have some stimulus signals. This issue is very important for market operator and consumer, too. In this mechanism, payment as installed capacity should to pay similar to mechanism of other countries. It have been shown that, this case cause to increasing the tendency of Genco's to improving conditions of their generation units for best profit in short term and for investing in long term. It is clear that the amount of generation and consumption is not in idealistic conditions, so this approach is more efficacious than implementation of full rivalry mechanisms. In these conditions, end user demands and the amount of generation will manage and are going to a balanced comparative mood.

Corresponding Author:
Mohammad Sadegh Javadi
Department of Electrical and Electronic Engineering, Islamic Azad University, Science and Research Branch, 73715-181, Fars, Marvdasht, Iran
E-mail: msjavadi@gmail.com

References

1. R. Green, "Draining the pool: The reform of electricity trading in England and Wales," Energy Policy, 1999, 27:515–25.
2. G. B. Shrestha et al., "Strategic bidding for minimum power output in the competitive power market," IEEE Trans. Power System, 2001, 16: 813–8.
3. D. Kirschen, G. Strbac, Fundamentals of Power System Economics, John Wiley & Sons, 2004.
4. M. Shahidehpour, H. Yamin, and Z. Y. Li, Market Operations in Electric Power Systems, New York Wiley, 2002.
5. K. Bhattacharya, M.H.J. Bollen, J.E. Daalder, Operation of Restructured Power Systems, Springer, 2001.
6. M. S. Javadi, H. Monsef, Security-Constrained Unit Commitment in Restructured Power system considering the reliability issues, Power System Conference 23rd, 2008, Iran.
7. M. Javadi, R. Azami, H. Monsef, Security Constrained Unit Commitment of Interconnected Power Systems, International Review of Electrical Engineering I.R.E.E, 2009, 4(2):199-205.
8. François Bouffard, Francisco D. Galiana, and Antonio J. Conejo, Market-Clearing with Stochastic Security- Part II: Case Studies IEEE Trans. Power System, 2005; 20(4):1577-83.
9. K. Soheily, Energy Demands, Theories, Models and Patterns for Iran, Razi University Publication, 2000.
10. Iran Regulatory Market Commission, Energy Surplus Instruction 88, available in: www.IGMC.ir

3/8/2011