DETERMINING SPOT PRICE AND ECONOMIC DISPATCH IN DEREGULATED POWER SYSTEMS

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Abstract- This paper presents a new formula for determining spot price and a new algorithm for economic dispatch in deregulated power systems. According to participant's biddings, an independent system operator (ISO) manages deregulated power systems (DPS) and decides transaction between participants. ISO aims to obtain minimum cost for entire power system. However each participant aims to work with minimum cost for only themselves. Each participant in DPS shares expensive operating and upkeep costs. Energy sources are used more efficient. Energy prices are determined according to the costs. The proposed algorithm considers price / power bids, generating / demand balance and generating units' constraints. The results are shown on the IEEE 30 bus standart test system.

Key Words- Deregulated Power Systems, Spot Price, Cost Minimization, Economic Load Dispatch.

1. INTRODUCTION

In recent years the electric power industry has been undergoing unprecedented restructuring all over the world [1]. For a participant of electric power system two things need to be fully examined. Firstly the relationship between competition requirements and the market structures secondly optimal operation of supply and demand in terms of social welfare [2]. In this respect many researcher used different methods for determining spot prices in deregulated power systems. In this paper, we presented a new computation approach for determining spot prices and load dispatch algorithm together.

In competitive electricity markets, to supply deregulation both production and consumption side which is necessary for reaching aims is very important [3]. After 1 July 2004, all consumer except domicile for EU member country are been free consumer. After 1 July 2007, all consumers for EU member country would be free consumer. In this respect, required studies must be making in deregulated electricity power market structure and operation for working regularly.

Economic load dispatch method which is run only according to participants' bids has many problems. The participants which are bids expensive or much production costs in near future may have to sell at loss. The aim is not expensive electrical energy, is determining the electrical price according to costs. Thus participants can do required investment as confident and in the course of time the participants may find a way more cheap electrical energy production. In this respect, in deregulated power market operations, spot price applications and participants' bids must put into practice together.

2. DEREGULATED POWER SYSTEM STRUCTURE AND SPOT PRICE APPLICATIONS

A centralized economic dispatch is employed to determine the market clearing price, the power generation and demand levels of all units and consumers. The competition in the electricity market must been encourage for investments to the new technology and more productive electrical source.

The participants in deregulated power market are independent power producer, distribution company. Bids are for supplying loads because all participants in the power system each other effect. The bids are been received by independent system operator. 1S0 analyze the power system situation, develop strategies and define transactions among participants by looking for the minimum price that satisfies the power demand [4].

According to many system operations each power production participant defines its own resource scheduling and sends a bid to the ISO for supplying other loads. The participants submit hourly offers that contain quantity and price, and they receive dispatch instructions from the ISO for each 5-min period. ISO determines transaction between participants according to their bids and power demand [5-8]. Transaction payments are defined as the product of the spot price and power transactions for each participant.

In a real competitive power market, no participant can absolutely control the power system operation. It means that the participants can not significantly affect the existing spot prices by adjusting their bids but mostly match the spot price with their marginal costs. Therefore the minimum power system operation cost and the maximum participant benefit are reached at the same time in a real competitive power market [9]. Benefit for a participant is calculated as:

$$B_i = -\Delta F_i + \rho.T_i + k_i.DF_{total} \tag{1}$$

$$\Delta F_i = F_i^{before} - F_i^{after} \tag{2}$$

The total benefit is calculated as the difference between costs before and after transactions:

$$DF_{total} = \sum_{i=1}^{GN} F_i^{before} - \sum_{i=1}^{GN} F_i^{after} \tag{3}$$

This difference is divided among participants.

Where k_i is $\sum_i k_i = 1$.

k_i is defined by ISO for each participants.

If spot price for one praticant (or bus) determined as optimum as seen in Figure-1, participants dont want transaction except own production. Participants will product electrical energy for only own agreement. Participant will export power if the spot price higher than ρ_{i0}. If the spot price is lower than ρ_{i0}, participant reduce own local generation. As in condition, power flow increase and than power cost increase too. Power system must have extra supply for this lack of restriction of participants. If the power systems have no extra supply, then spot price applications can't apply regularly.

Spot prices which are defined by ISO are change according to power production units and transmission lines in the power system [10]. 1S0 does not know the actual operation costs of the participants in deregulated power system. 1S0 can infer their marginal costs by accepting bids and collecting operation data over a long period of time. ISO must provide to supply all demand power. If total power demand higher than participants' offer spot price will increase. Conversly, if total demand power lower than participants offer, spot price will dicrease. This situation is known in literature as 'real time closed loop control rule' [11]. Export or import electrical powers change in all period according to participant's unit constraints. All electrical power producers want to run their units in the most productive operation conditions in every period.
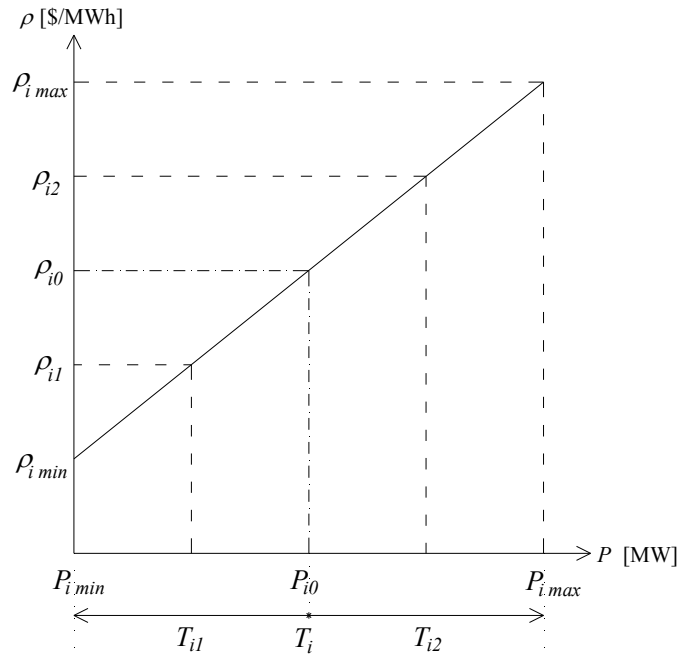

Figure 1. Power productions - Bids

Fuel cost curves of the generation units must known truly by own participant. At the same time, unit's power generation life takes into consideration. In a real competitive power market structure must pass to cost based tariff model [12]. Power production units must been privatize rapidly as harmonious with electrical market aims. It is only one key for successful electrical power market reform is cost based prices in the passing time [3].

As seen in Figure-2 the more power demand increase the more spot price increase for variable case. Therefore, for a production unit which is run full capacity during all day, electrical energy prices is same during all day, too. Spot prices follow the shape of the demand power profile approximately in every period [13, 14].

Every seller and every buyer must be very small compared with the size of the electrical market for perfect competition. The participants can not significantly affect the existing spot prices. Spot price is not a function of the participants' generation. Participant's benefits are maximized when the marginal cost corresponds to the spot price [15].

While we determining spot prices for one participant, we must do calculate average price according to power production density as seen follow:

$$\rho_{ti} = \frac{\rho_{ti1}.P_{i1} + \rho_{ti2}.P_{i2} + \rho_{ti3}.P_{i3} + ... + \rho_{tin}.P_{in}}{P_{i1} + P_{i2} + P_{i3} + ... + P_{in}} \tag{4}$$

Spot price application is put into practice in all case except between participants' agreement for power transaction. In deregulated power systems, a participant can sell electrical energy to own customer with agreement price between themselves. Electrical energy prices are calculated with spot prices except reciprocal obligation.
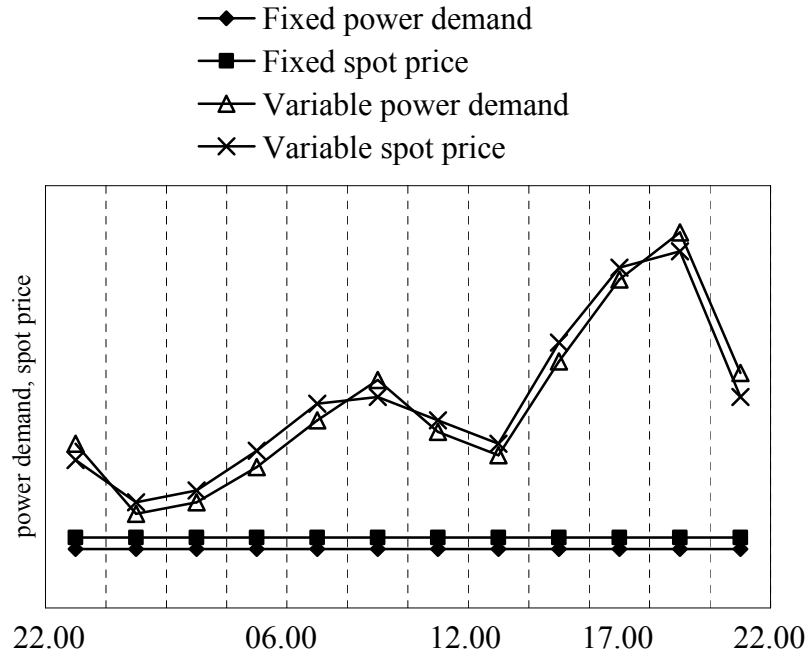

Figure 2. Demand and spot prices

Spot price is very important in deregulated power system management. Therefore, many researchers study for determining spot price. Some spot prices formulas in the literature are given in Table-1.

Table 1. Different spot price calculation methods

Literature	Spot price of actual power
[1]	$\rho_i^p = (1 - \frac{\partial P_L}{\partial P_i})\lambda_{ps} - \frac{\partial Q_L}{\partial P_i}\lambda_{qs} - \sum_{j=1}^{l}(\pi_{llj} + \pi_{ulj})\frac{\partial P_{lj}}{\partial P_i}$
[11,16]	$\rho_{(t)} = \frac{\partial C(P(i,t))}{\partial P(i,t)} + \sum_{l}\mu_l F_l(t)$
[17]	$SP_{ik,j} = \lambda_{i,j}\left(1 + \frac{-TP_{ki,j} - TP_{ik,j}}{TP_{ik,j}}\right)$

3. A NEW ECONOMIC LOAD DISPATCH AND SPOT PRICE ALGORITHM

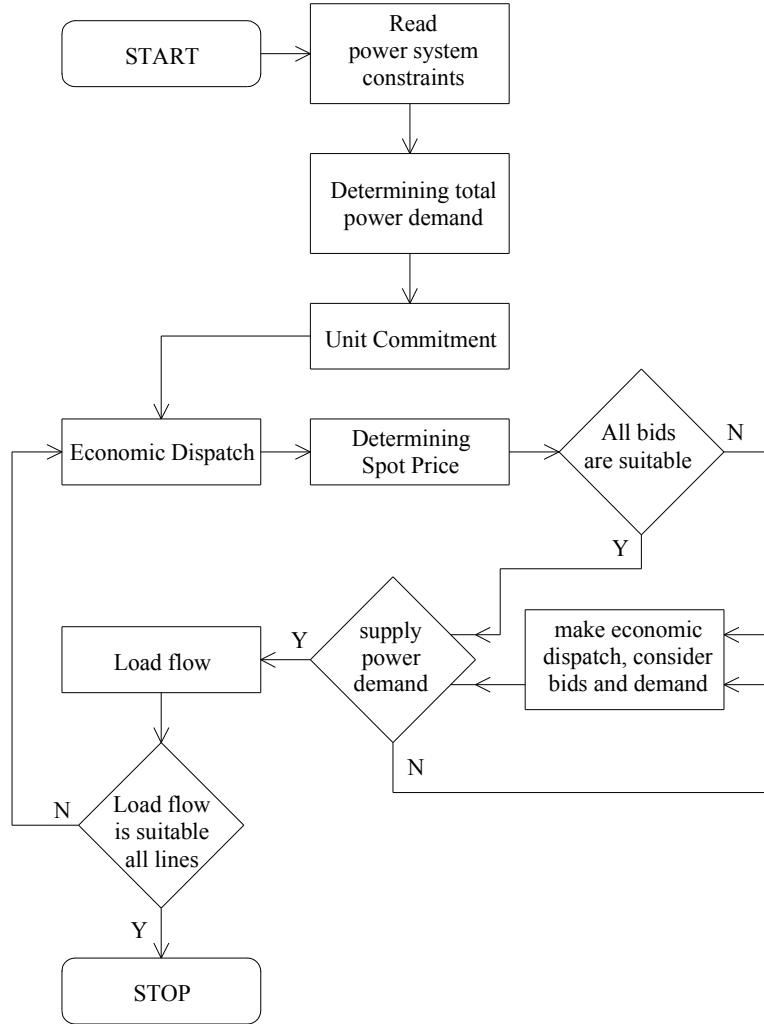The proposed new economic dispatch and spot price algorithm (Figure 3) is given as follow:

Figure 3. Proposed load dispatch algorithm

The proposed new algorithm considers power system and production units constraints and participants bids for determining spot price and economic load dispatch. While we calculating spot prices supply-demand equilibrium and production units power output are considered too. In this respect below spot price equation (Eq.-6) is improved and utilized in the proposed method.

$$\rho_{(t)} = \frac{\partial C(P(i,t))}{\partial P(i,t)} + \sum_l \mu_l F_l(t) \tag{5}$$

$$\rho_t = \frac{\rho_{(t)}.P_i + \rho_{(t)}.P_{Tj}.cur}{P_i + P_{Tj}} \tag{6}$$

$$cur = \frac{P_i}{P_{i\,max}} \cdot \frac{P_{Dt}}{P_{Tt}} \qquad\qquad (7)$$

cur (capacity usage ratio) is spot price coefficient for only P_{Tj}. Because power production unit has run on *P(i,t)* power in the preceding period. *cur*, express relation between demand, bids and production capacities in its period. *cur* increase spot price increase, *cur* decrease spot spot price decrease. While we determining electrical energy prices, we must consider amortizaton and back payment for units debts. In this respect, it is important that production unit's lifelong power production and its effect to unit cost.

Load flow must analysis to consider regional power demand. Appropriateness to load flow of load transmission capacity of transmission line must control. Load dispatch and load flow analysis realize again for cases are not suitable. The proposed algorithm considers units actual power limits, national demand equilibrum and participant bids.

4. TEST RESULTS

Test system data for applications the proposed new algorithm are given in Table 2 and Table 3. Table 2 and Table 3 data are been received from Yan 2001.

Table 2. Test system properties

Number of buses	30
Number of units	6
Number of branches	43
Number of tie lines	6
Total power demand in MW	283,2

Table 3. Production units' properties

Generator no	P_{max}	Cost coefficients	
		b_i	a_i
1	80	1,083	0,074
2	70	1,033	0,089
3	70	1,033	0,089
4	80	1,083	0,074
5	70	1,033	0,089
6	100	1,170	0,053

Economic load dispatch and their costs comparisons are given in Table 4. According to data which are given in Table 4; power production cost is decrease more 36 $ per hour for same power production in the system. In this case power system total production cost is decrease, benefit of participants are increase. Thus more productive economic load dispatch is done.

Spot price calculation results and comparison with literature for all buses in the power system are given in Figure 4.

El-Keib (1997) spot prices and proposed method spot prices are given in Figure 4 for the IEEE 30 bus standart test system in the same case study. Spot prices are decrease in all bus which are no product electrical power.

Table 4. Comparisons

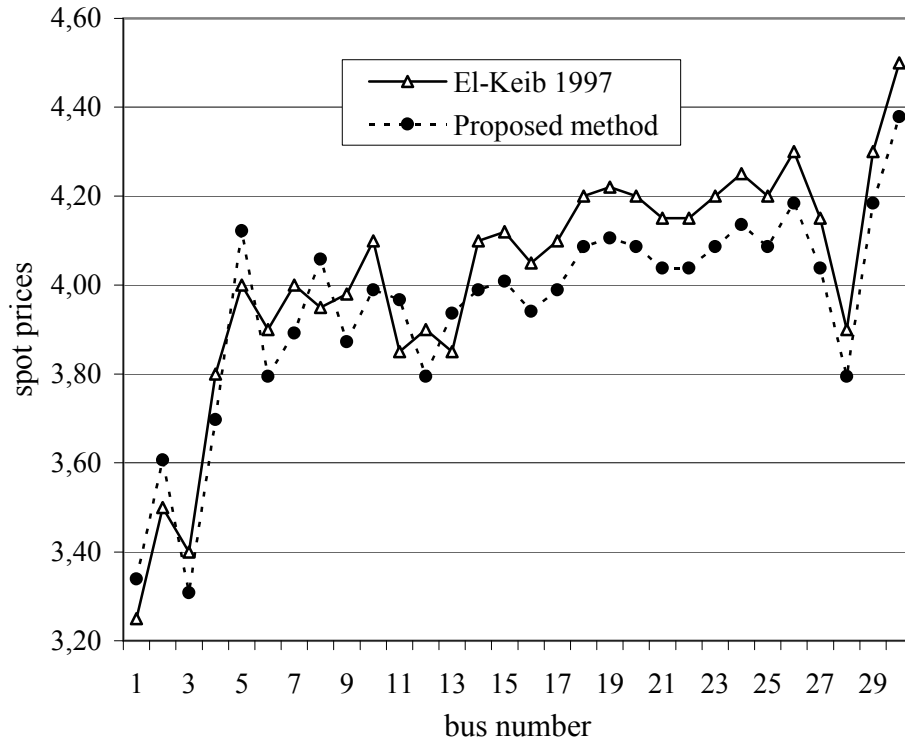| Gen. No	Yan 2001		Proposed method	
	P [MW]	Cost [$/MWh]	P [MW]	Cost [$/MWh]
1	62,9	361,46	49,13	231,82
2	33,8	136,60	44,02	217,93
3	51,8	293,20	44,02	217,93
4	44,7	197,14	49,13	231,82
5	33,8	136,60	44,02	217,93
6	63,8	291,48	60,32	263,41
Total	**290,8**	**1416,48**	**290,64**	**1380,86**

Figure 4. Comparison of spot prices

5. CONCLUSIONS

In this paper we presented a new algorithm for determining spot price and economic load dispatch in deregulated power systems. The proposed algorithm runs according to power system and generation units' constraints. Different researcher' methods are evalution. General properties of the spot price applications in many countries are explained. We proposed a new formula which is consider participants bids, total load demand and supply power for calculating spot prices. The proposed algorithm is tested in the IEEE 30 bus standart test system which has 6 generation units. Economic load dispatch and spot price determining are studied in the proposed algorithm. Consequently, the proposed algorithm and spot price calculation method are suitable for deregulated power system according to obtain from case study data. Thus, power supplies in the deregulated power system are used more productive and more favourable to competition.

6. NOMENCLATURES

cur : Capacity usage ratio
i : Bus number
GN : Generator number
F_i^{before} : Cost before transaction [$/h]
F_i^{after} : Cost after transaction [$/h]
ΔF_i : F_i^{before} - F_i^{after} [$/h]
$Fj(Pj)$: Fuel cost j. generation unit [$/h]
DF_{total} : Difference the costs. [$/h]
λ : System lambda, Lagranrian multiplier
P_L : Total actual power loss [MW]
P_D : Demand power [MW]
P_{0i} : Actual power of i. bus [MW]
P_{Bi} : Demand power of i. area [MW]
P_{Tj} : Load supplying bid for j. unit
P_{Sj} : Load shedding bid for j. unit
P_f : Actual power for f. transmission line
$\rho_t,\ \rho_i^p$: Spot price for t. period [$/MWh]
k_i : Participant factor
B_i : Benefit of i. participant [$/h]
T_i : Power transaction [MW]
$P_{i,min}$: min. power constraint for i. unit [MW]
$P_{i,max}$: max. power constraint for i. unit [MW]
P_{Dt} : Total demand power for t. period [MW]
P_{Tt} : Total offer power for t. period [MW]

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