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Analysis of LMP in a Competitive Electricity Market

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Abstract

Locational marginal pricing (LMP) is the least cost required to supply the cost of the increment of electrical energy at a specific location in a given system. In this paper, locational marginal pricing in a deregulated market has been analysed for an IEEE 6-bus system. The outputs have been figured out to show the relationship between the generator bids, load bids and load demands. Maximization of Social welfare is taken as the objective function. The simulation is done by using PSAT software in MATLAB. The values of LMP has been analysed in all buses and social benefit has been analysed.

1 Introduction

In a vertical integrated power system, power generation, transmission and distribution are supervised by a single entity. Whereas in a deregulated power, entities like Generation companies (GENCO), power transmission companies, power distribution companies, independent system operator, retailer are independent.The deregulation process mostly focuses on enhancing system efficiency, improving service standards and developing competitive market. The reliability and security of whole power system is the answerability of the Independent System Operator (ISO). The basic LMP formulation has been briefly explained in [1]. DC optimal power flow based linear programming approach has been discussed in paper [2]. LMP forms the basis for transmission pricing calculations [3]. The calculation of LMP with a comparison between DC and AC power flow model has been studied in papers [4-5].The relationshipship between generator bids and load bids with LMP formulation has been presented in [6]. The performance analysis of LMP varies with congestion in transmission lines has been dealt in [7]. In paper [8], a discussion on the variation of LMP price has been presented with regard to its market design. An approach to minimize the congestion in deregulated power market using LMP methodology has been dealt in [9]. OPF based congestion management solution using Genetic Algorithm (GA) has given best economical results for minimizing system operating cost [10]. The inclusion of series FACTS device in LMP problem formulation is one of the techniques to maximize social and economic welfare with reduction of congestion [11]. This paper deals with the congestion management carried by Optimal Transmission Switching which relieves congestion [12]. A Congestion management technique incorporating Renewable Energy Resources (RER) has been proposed wherein Independent System Operator (ISO) have to responsibility to propose the size and appropriate site for the implementation of RER based on reduction of LMP pricing [13]. The bidding natures of the rival participants predicted by the Monte Carlo Simulation (MCS) for the double sided biding optimisation problem has been proposed using Bacteria Foraging Optimisation (BFO) to obtain the optimal bidding strategy [14]. An enhanced Shift Load Factor (SLF) based Line Outage Distribution Factor (LODF) LMP congestion management technique has been presented in paper [15] in a deregulated scenario for relieving congestion.

2 Problem Formulation

The OPF-based approach is basically a non-linear constrained optimization problem subjected to equality and inequality constraints. Here the objective function is the minimization of gap between supply and demand so that maximization of social welfare function is attained in electricity market design as given below:

$$Min - \sum_i C_{Di}(P_{Di}) - \sum_i C_{Si}(P_{Si}) \quad (1)$$

Subject to

$$0 \leq P_{Si} \leq P_{Simax} \quad (2)$$
$$0 \leq P_{Di} \leq P_{Dimax} \quad (3)$$

where Csi and CDi are the cost function of supply and demand bids of the ith unit in $/MWh respectively. PSi and PDi represents the supply and demand building bids in MW.

3 Locational Marginal Pricing

The LMP at a location is defined as the marginal cost to supply an additional MW increment of power at the location without violating any system security limits.The concept of an LMP (also called a spot price or a nodal price) was first developed by Schweppeet al (1998). LMPs can be derived using either an AC OPF model or a DC OPF model.The AC OPF model is more accurate than the DC OPF model, but it is prone to divergence. Also, the AC OPF model can be up to 60 times slower than the DC OPF model. The DC OPF model (or the linearized AC OPF model) has been widely used for LMP calculation for power market operation. Several commercial software tools for power market simulation such as VentyxPromod IV, ABB GridView, Energy Exemplar PLEXOS , PSAT Matlab and Power World use the OPF models for power system planning and LMP forecasting.

4 RESULT AND DISCUSSION

The test system considered here is the IEEE 6-bus system . The test case has been simulated using MATLAB-PSAT software. There are 6 buses in which 3 buses are generating bus represented GENCOS (Generating Companies) and 3 load buses represented as DISCOS (Distribution Companies). The GENCOs provides linear supply bids whereas the DISCOS provides linear demand bids. IEEE 6-bus test system is considered to analysis the LMP and to achieve the social welfare maximization from the OPF using a Primal-dual Interior Point technique. The modelled IEEE 6-bus system is modelled in PSAT matlab as shown in Figure 1 and the input parameters are tabulated in Figure 1. GENCOs Power Generation limits and the DISCOs Power demand limits are listed in Table 2 and Table 3 respectively. LMP values obtained are analyzed at each bus is depicted in Table 4. Thus from the above simulation, the Total Transaction Level (TTL) is obtained as 323.0698 MW and optimal value of pay off with Independent Market Operator is \$61.2033/hr as analyzed in Table 5.

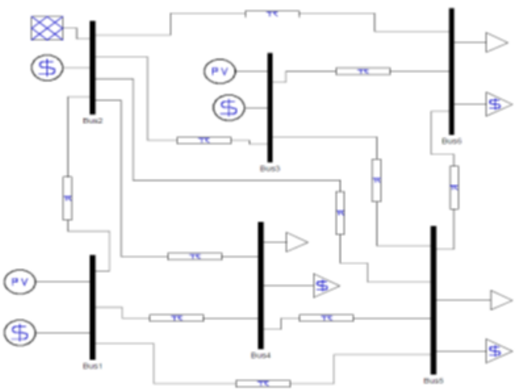

Figure 1 IEEE 6-bus Simulation model

Input Parameters	No.
Buses:	6
Lines:	11
Generators:	3
Loads:	3
Supplies:	3
Demands:	3

Table 1 Input Parameters

Bus	P_Si min [MW]	P_Si [MW]	P_Si max [MW]
Bus1	0	0	20
Bus2	0	25	25
Bus3	0	20	20

Table 2 GENCOs Power Generation limits

Bus	P_Di min [MW]	P_Di [MW]	P_Di max [MW]
Bus4	0	25	25
Bus5	0	10	10
Bus6	0	8.0693	20

Table 3 DISCOs Power demand limits

Bus	P [MW]	Q [MVar]	LMP [$/MWh]	NCP [$/MWh]	Pay [$/h]
Bus1	90.001	44.77413	9.01023	-0.04483	-805
Bus2	164.8754	77.19236	8.87032	0	-1469
Bus3	80	73.85958	9.08423	0.070476	-726
Bus4	-115	-76.665	9.48576	0.193035	1091
Bus5	-110	-77	9.62532	0.270066	1053
Bus6	-98.0079	-65.3385	9.38763	0.222384	917

Table 4 LMPs at different buses

Output Parameters	Output (MW)
Total Transaction Level	323.0698
Total losses	11.868
Bid losses	1.993
IMO PAY [$/h]:	61.2032

Table 5 Social benefit analysis

5 Conclusion

Thus the analysis of Locational Marginal Pricing has been carried out on a IEEE-6 bus system with the objective of social welfare maximization using PSAT. This proves the effectiveness the proposed approach in analyzing the social benefit between the GENCO and the DISCO.

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