Study of Optimal Dispatching Strategy of Demand Side Bidding Considering the Network Constraints

CHEN Xingying, CHEN Lu, LIAO Yingchen
Hohai University–China
E-mail address: xychen@hhu.edu.cn

ABSTRACT

Demand-side bidding (DSB) provides a very flexible way of meeting the peak load in a production schedule, which is benefit for both power companies and consumers. In the electricity market with opening demand side, the model of optimal dispatching strategy of DSB was formed considering network constraints maximizing the interests of power companies, where DSB was viewed as power resource, then the optimal dispatching solution was determined by Primal-dual interior point algorithm. Numerical results of an IEEE14-bus example have showed the efficiency of the proposed model, and demonstrated that DSB project can control the distribution price.

INTRODUCTION

The appearance of Demand Response(DR) makes the peak power dispatch with demand side possible, and plays an important role in reducing the peak load, relieving the network congestion and saving energy, etc[1].With vigorously pushing forward the smart grid, the electricity market with opening demand side will become an inevitable trend. In this environment, as an important implementation mechanism, DSB allows comsumers to change own loads by way of active participation in market competition, not only obtaining the corresponding economic compensation, but also inhibiting the electricity market price volatility and reducing risk to achieve a win-win situation.

The research of DSB are mostly concentrated in two areas recently, one is considering how to determine their bidding strategy to maximize revenue from the demand side, primarily through the game theory [1]-[4] or bidding function [5], the other is analyzing the effect of DSB on the power system [6], such as to qualitatively analyze the influence of DSB on the average price of peak periods and daily electricity price volatility[7]-[9], the influence of DSB on the generation side [10], and the mathematical model is derived that it's easy to cause price spikes if consumers can't make unreasonable arrangements after the reduction of the load[11]. Literature can be seen from above, the research1 of how to dispatch the demand side of is little, but with the extensive application of DSB [12-13], optimal DSB dispatching is very important to power companies.

We considers DSB agents, and only some power to compete, according to the sub-time marginal cost pricing of DSB, on the basis of optimal power flow, the model of optimal dispatching strategy of DSB considering the network constraints is proposed satisfying the power flow equations with the introduction of demand-side "negative watts" resources, where put the cost and corresponding benefits of DSB into the objective function, considering the voltage amplitude, phase angle constraints and available transfer capability limitation of lines, then study the effect of DSB in running the power grid, network losses and costs of power companies through the Primal - dual Interior Point Algorithm.

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DISPATCHING STRATEGY OF DEMAND SIDE BIDDING CONSIDERING THE NETWORK CONSTRAINTS

Assumed in the day-ahead market, and only some power to compete, large comsumers can directly participate in bidding and small consumers can bid in the form of agents, as shown in Fig. 1. For simplicity, power companies and ISO are classified as a class, DSB agents are seen as the demand side. The bidding and dispatching process are: Firstly, DSB agents and generators report their own information bid in the form of "Time-Capacity-Price" to the ISO/power companies in advance (information flow). ISO/power companies determine optimal dispatching by the results of optimal power flow based on forecasting load satisfying network constraints, then dispatch relevant results(how and how many) back to the generators and DSB agents (information flow). Finally, generators supply power to systems (energy flow), DSB agents supply or comsumer "power" according to the final dispatching results in the second day (energy flow).

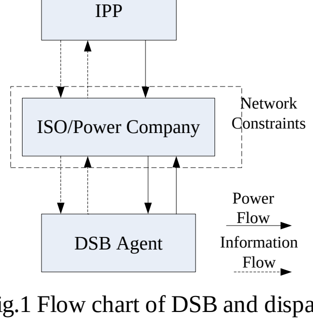

Fig.1 Flow chart of DSB and dispathing

Model of Dispatching Demand Side Bidding Considering the Network Constraints

We think about single-period DSB dispatching problem, putting the compensation fee of DSB(the comsumers' bidding costs) into the cost of power company.The objective function aims to minimize the cost of power companies and maximize economic benefits mathematically expressed as follows, while operating costs include the cost of purchasing electricity, network loss and compensation fee. The cost of purchasing electricity can be expressed as a quadratic function of active power in a fixed moment, the network loss is translated into corresponding cost through a coefficient, and compensation fee is determined with the bidding curve.

$$\min f = \sum_{i=1}^{n} C\left(P_{Gi}\right) + \sum_{i=1}^{n} u_i \rho_{DSBi} P_{DSBi} + \alpha \cdot \left(\sum_{i=1}^{n} P_{Gi} - \sum_{i=1}^{n} \left(P_{Di} - u_i P_{DSBi} \right) \right) \tag{1}$$

Where $C_i(P_{Gi}) = aP_{Gi}^2 + bP_{Gi} + c$ is cost function of purchasing electricity in a fixed moment, α is conversion coefficient of network loss, P_{Gi} is the active input of node i , P_{Di} is the active load of node i , u_i is a decision variable (0-1 variable), where $u_i = 1$ means DSB node i participates in dispatching ,and $u_i = 0$ means DSB node i isn't involved in dispatching, ρ_{DSBi} is the unit electricity cost of DSB node i , P_{DSBi} is the active load of DSB node i in the auction.

Firstly, it should meet active power constraints, ignoring reactive power constraints, where equality constraints is the active balance equation, and inequality constraints includes constraints of electricity purchasing、node voltage and branch active power. The mathematical expressions are as follows:

$$\begin{aligned} & P_{Gi} - P_{Di} + u_i P_{DSBi} \\ & -U_i \sum_{j \in i} U_j \left(G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij} \right) = 0 \\ & P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \\ & U_i^{\min} \le U_i \le U_i^{\max} \\ & P_{ij}^{\min} \le P_{ij} \le P_{ij}^{\max} \end{aligned} \tag{2}$$

Where $j \in i$ is node j connects with node i , G_{ij}, B_{ij} is the element of node admittance matrix, θ_{ij} is the phase difference between node i and node j , U_i, U_j is the voltage amplitude of node i, j , P_{ij} is the active power of branch ij , from i to j .

Secondly, the maximum outage capacity constraints should be satisfied which is limited by the normal electricity consumption and consumers' characteristics. In the reported bidding curve, there is a range of maximum and minimum bidding curve, which dispatching load must meet.

$$P_{DSBi}^{\min} \le P_{DSBi} \le P_{DSBi}^{\max} \tag{3}$$

Where $P_{DSBi}^{\min}, P_{DSBi}^{\max}$ is the minimum and maximum interrupt capacity of DSB node i .

Solving Process

We solve the optimal power flow model through Primal-dual interior point algorithm, whose general solution steps are: Firstly enter basic data such as DSB, etc. and transfer inequality constraints into equality constraints through the buffer variable, then change the target function into the new Lagrange function using the logarithmic barrier function, finally get the optimal solution by continuous revision and iteration. According to short-term marginal cost pricing theory, the distribution price is equal to increment ratio of system cost to each node's active load. The λ in the model exactly has the economic significance, whose flow chart is in Fig.2.

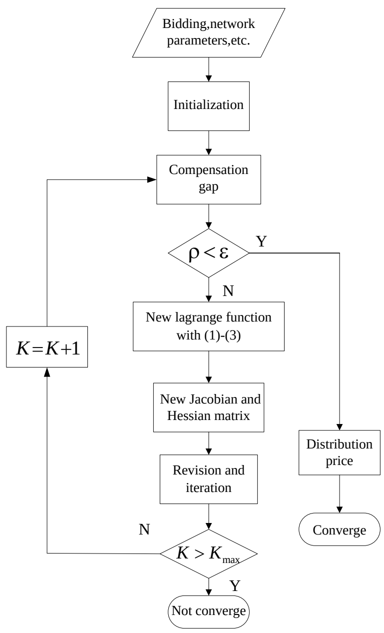

Fig.2 Flow chart of optimal dispatching strategy of DSB considering constraints

NUMERICAL EXAMPLES

This example is on the basis of IEEE14-bus example[14],in which node 1,2,3,6,8 are generation node.Due to high price of node 7 and 9, the power company choose the two nodes as dispatching nodes of demand side, namely "negative watts" node. Node loads before DSB are shown in Tab.1, and part capcity of node 7 and 9 paticipate in the programme. Node loads are 10MW and 20MW respectively, and bidding range are [5MW, 12MW] and [10MW, 15MW], bidding price is 45 $/MW and 38 $/MW.

Tab.1 Node lodes before DSB(MW)

Node	Load	Node	Load
1	10	8	15
2	21.7	9	29.5
3	93.2	10	9
4	47.8	11	13.5
5	7.6	12	6.1
6	21.2	13	33.5
7	17	14	14.9

Firstly, we discuss the case of a single dispatching node 7, whose price is shown in Fig. 3. Because of a single dispatching node 9 which is affected by many factors, convergence results are not satisfactory, and network loss is quite high about 51.87MW, we decide to ignore this case. Finally we discuss the caseof dispatching node 7 and node 9 meanwhile, whose price is shown in Fig. 3.

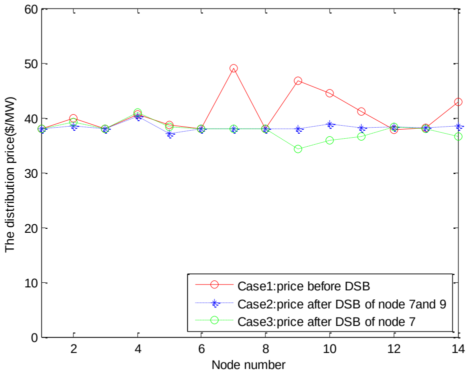

Fig.3 The distribution price before and after DSB

It can be seen from Fig.3, the order of size of the average distribution price is: Case 1> Case 2> Case 3, the order of size of price fluctuations is: Case 1> Case 3> Case 2. Case 3 has the lowest average price after the implementation of DSB of node 7, but price volatility is not desirable. Case 1 is s an ideal state, where there is relatively large decline in the average distribution price, and the difference with lowest average price is smaller, while price volatility is little.

Active power and network losses under the three case are shown in Tab. 2 and 3.From them, we can see the impact of DSB on power system, that all the average price declined, from $ 40.81 / MW down to $ 38.28 / MW in case 2 and to $ 37.73 / MW in case 3, decreased by 6.2% and 7.5% respectively. Although the total system load and active power declined, the network losses rose to a certain extent, increased 14.0% of case 2 and 11.2% of case 3. Both active power costs and DSB fee are reduced compared with case 1, and the following order: Case 1> Case 3> Case 2.

Tab.2 Active power input with DSB(unit:MW)

Node	Case1	Case2	Case3
1	177.35	171.76	175.99
2	50	50	50
3	64.89	50	56.79
6	39.05	25.50	21.60
8	24.44	22.82	26.65
7	0	10.04	9.94
9	0	11.19	0
Total	355.73	341.31	340.97
Network loss	15.77	17.93	17.55

Tab.3 The electric cost under three cases(unit: $)

	Case1	Case 2	Case 3
Cost of purchasing	9810.7	8759.5	9316.4
Cost of loss	599.3	681.3	666.9
Cost of DSB	0	877.0	377.7
Total cost	10410	10317.8	10361

Understandably, different nodes participate in the bidding has diverse impact on the power system. It can not be generalized that more nodes in, the situation better. The best result is related to power system itself and comsumers' bidding. In this paper, Case 2 is the best. There is one thing we are certain that the demand side's participation can ensure the stable operation of the electricity market better.

CONCLUTIONS

In the electricity market with opening demand side, based on optimal power flow, the model of optimal dispatching strategy of DSB considering the bilateral system of bidding on power system is proposed. Examples show that comsumers'participation at the peak period is an effective way in dispatching, which can reduce peak load to ease the problem of insufficient power supply, to ensure continuous, healthy and stable operation of electricity market.

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BIOGRAPHY:

CHEN Xingying(1964-), female, doctoral supervisor, Main research directions: Economic operation analysis and control of power system, Electricity market and power economy, Operation analysis and control of renewable energy power systems. E-mail: xychen@hhu.edu.cn

CHEN Lu (1987-), female, graduate, Main research directions: Demand Side Management.
Email: chenlu0131@yahoo.com.cn

LIAO Yingchen (1975-), received her B. Eng degree from Hohai University, Nanjing, China, in 2000. Currently she is a Ph.D. candidate in electrical engineering in Zhejiang University, Hangzhou, China, and a lecture in Hohai University. Her major field of study is Electricity Market and Demand Side Management.
Email: yingchenliao@gmail.com