

# The Calculating Method of Power Supply Capacity Considering the Balance of Benefits of Electricity Selling Companies

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**Abstract.** In this paper, after the sales side is released, the power supply capacity of the power grid is evaluated. Firstly, based on the benefit distribution model of the cooperative game, the profit distribution result of the seller's members is calculated. Then reverse the purchase of electricity by each of the electricity sellers. Finally, the calculation method of power supply capacity of distribution network considering the interests of power sales companies is proposed.

**Keywords:** balance of interests; different time scales; distribution network; power supply capacity.

## 1. Introduction

Power supply capacity of modern power grid is an important indicator [1]. Currently, many provinces and cities in China are facing the pilot of electricity selling side liberalization. More than 3,000 power selling companies have been publicized in power trading centers across the country. Different from the traditional situation, in the market environment, the power supply capacity of the power grid is not only restricted by physical system but also affected by transaction behavior [2].

So far, the research on power supply capacity of distribution network is divided into three stages: the stage of evaluating distribution network capacity distribution[3]; Study the stage of considering network transfer capacity of distribution network power supply capacity[4-5]; Comprehensive consideration is given to the n-1 safety criterion of distribution network, substation capacity and the stage of network switching capacity[6-7]. At present, there is no literature on the assessment of power supply capacity in the case of balanced interests of power selling companies.

In this paper, according to the profit game model of the sellers of electric power under the contract for difference, according to the cooperation among the sellers and the Shapley value, and considering the reasonable profit distribution among the members of the alliance[2], the power supply capacity of the distribution network is calculated in the case of the balance of interests of each power selling company.

## 2. Profit Distribution Model of E-Commerce Sellers based on Cooperative Game

The trading price of the electricity market is related to the number of members in the e-commerce alliance. After the formation of the alliance, the overall profit will rise accordingly, and then the Shapley value method can be used to analyze the profit distribution among alliance members [2].

Set the inverse demand function of electric energy in the electricity market as:

$$P_c = \alpha - \beta q_e \quad (1)$$

Where,  $P_c$  is the market price of electricity trading,  $q_e$  is the total generating capacity of all power producers in the market,  $\alpha, \beta$  is the intercept and slope of inverse demand function. The electricity market is regarded as a monopoly market composed of N power producers, and the market price of electricity transaction is:

$$P_c = \frac{\alpha + \sum_{i=1}^N c_{gi} - \beta \sum_{i=1}^N q_{ci}}{N+1} \quad (2)$$

Where,  $c_{gi}$  is the unit electric energy production cost of generator I,  $q_{ci}$  is the quantity of electricity sold under the CFD signed by generator I.

Under normal circumstances, the number of e-commerce sellers  $M \geq 3$ , and the total profit after the formation of the alliance is larger than the profit before the formation of the alliance, so this paper only discusses the situation when e-commerce sellers participate in the alliance.

In this paper, Shapley value method is adopted to analyze the benefit distribution of members in the alliance [2]. The electricity sold by the alliance under the balance of interests is:

$$q_A = \frac{b \sum_{j=1}^M q_j + (a - p_c)}{2b} \quad (3)$$

Where,  $q_j$  is the total electricity sold by e-commerce j. Here,  $a = \alpha + \sum_{i=1}^N c_{gi}$ ,  $b = \frac{\beta}{N+1}$ .

### 3. Power Supply Capacity Evaluation Method Considering the Balance of Interests of Power Selling Companies

The power supply capacity function of the distribution network can reflect the safe operation level of the distribution network, and also represents the real-time operation state of the distribution network. In order to avoid large errors caused by the same proportion of load growth, this paper gives different growth models for the load amount at each load point according to its actual growth law. In the case of interest balance, the power flow distribution in the power distribution network can be calculated, and the maximum power supply capacity of the distribution network without blocking can be obtained. The calculation steps of power supply capacity of distribution network in the case of interest balance of each power selling company are as follows:

- (1) analyze the e-commerce alliance and calculate the profit of the alliance;
- (2) based on the analysis of e-commerce seller k within the alliance, all subsets including k in the alliance are set as  $S_i$ , the calculated cooperative profit and cooperative profit other than e-commerce seller k;
- (3) calculate the profit Shared by e-commerce vendor k after participating in the cooperation;
- (4) obtain the electricity purchased by each e-commerce seller and the power output of each power generator under the condition of interest balance;
- (5) given the initial value of load  $C = C_0$ , the system power flow can be calculated when the output of the generator and the node voltage of some generator are known;
- (6) make the load of each node continue to increase according to the actual load growth model obtained, and call step (5) repeatedly until the first over-limit occurs, denoting this time  $t = t_0$ ;
- (7) given accuracy  $\xi = \xi_0$ , let  $d = t_0 - 1, e = t_0$ , construct a closed interval  $[d, e]$  and use the half-division method to get the critical point that meets the accuracy requirements. At this time, the load value at load point i is  $P(a)$ ;
- (8) at this point, the total load value of each load node is the power supply capacity of the system. The calculation process of power supply capacity is shown in figure 1:

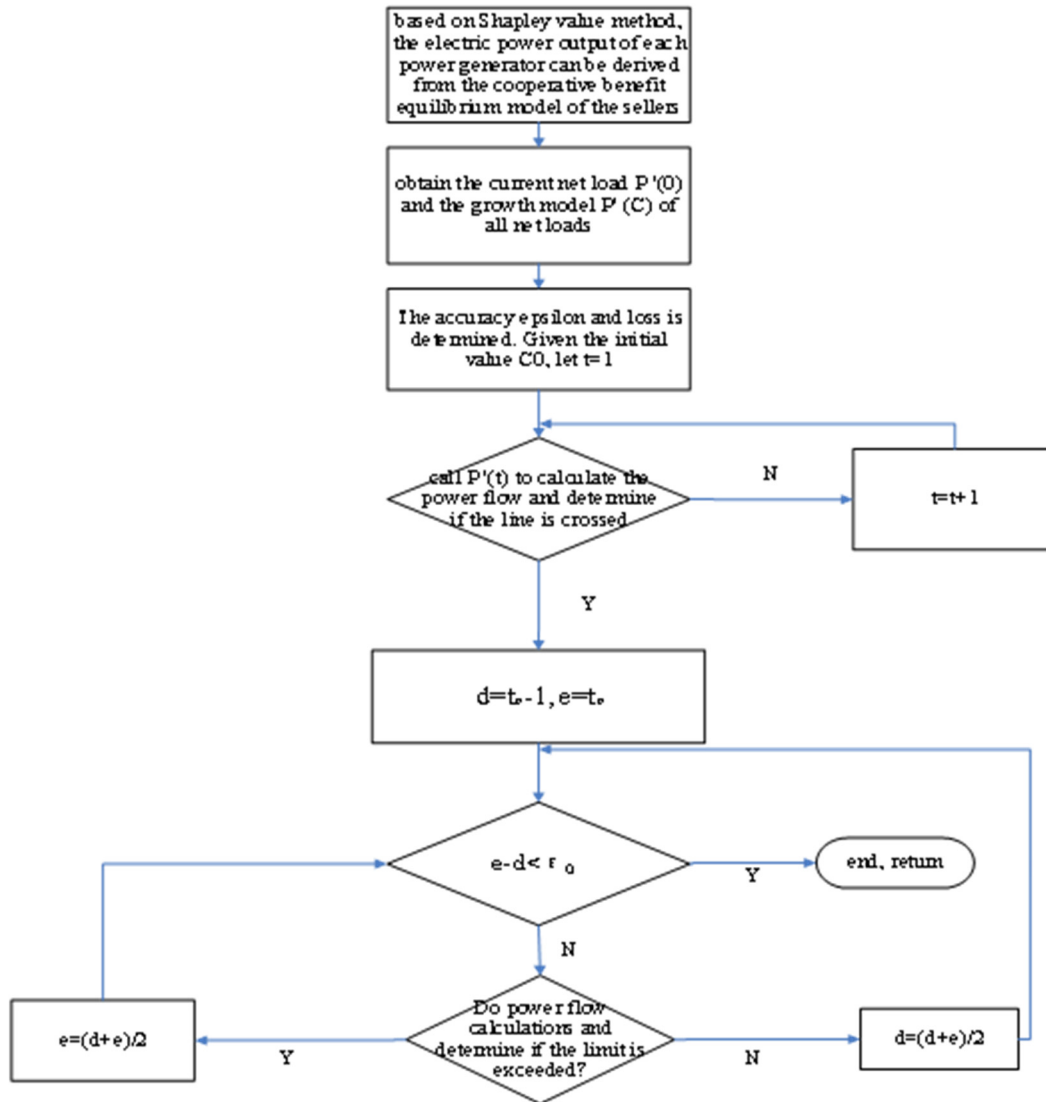


Fig. 1 calculation process of power supply capacity of distribution network considering interest balance of power selling company

#### 4. Analysis of Examples

The voltage level of the high-voltage distribution system in a certain region is 110kV, including 3 110kV hydropower plants (connected at 1, 2 and 3 respectively), 8 110kV lines, 10 110kV transformers and 10 10kV busbars. The wiring of the system is shown in figure 2.

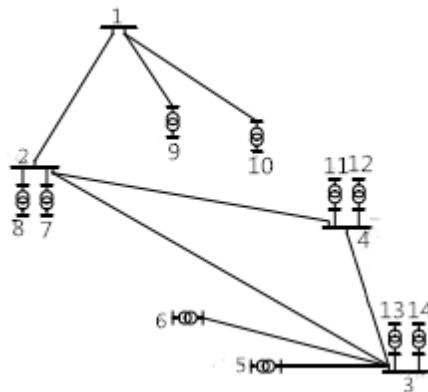


Fig. 2 distribution network topologies of a region

In this paper, hydropower is set as the generator in the market. If the unit electric energy cost of the generator is =254(yuan/MWh), the inverse demand function of electric energy is. Suppose that the price of price for CFD trading is set at 342 (yuan/MWh) after negotiation, there are three sellers in the market.

The market price of electricity trading decreases with the increase of the number of e-commerce sellers in the alliance, and the market price of electricity trading after the alliance is lower than the market price when these e-commerce sellers trade alone. By analyzing the decision-making results of the three e-commerce vendors in the cooperation situation, we can obtain the power generation of each generator while obtaining the result of interest balance, so that the load continues to grow, and then, when the distribution network is not blocked, we can obtain the electric energy purchased by each vendor from each generator as shown in the following table:

Table 1. generating capacity of each generator

	No. 1 e-commerce seller 17.2MWh	No.2 e-commerce seller 21.9MWh	No.3 e-commerce seller 15.0MWh
Generator No. 1 (MWh)	4.3	5.5	3.7
Generator No. 2 (MWh)	5.7	7.3	5.0
Generator No. 3 (MWh)	7.2	9.1	6.3

The power flow calculation results under the maximum load of the system are as follows:

Table 2. system power flow calculation results

Node number	The node voltage (p.u.)	Branch number	Branch power (MW)
1	1.052	1-2	3.47
2	1.042	1-9	4.82
3	1.013	1-10	3.56
4	1.008	2-3	3.43
5	0.989	2-4	3.87
6	1.017	2-7	3.91
7	0.976	2-8	5.12
8	0.965	3-4	4.01
9	0.953	3-5	4.13
10	1.017	3-6	3.07
11	1.025	3-13	4.21
12	0.967	3-14	3.41
13	0.984	4-11	3.72
14	1.007	4-12	4.25

In this case, the power supply capacity of the whole network is:  $S = 56.3MW$

To sum up, the power supply capacity described in this paper is limited compared with the situation that does not consider the balance of interests of power selling companies. The calculation method is simple, easy to program, and fully considers the growth law of load, thus providing an effective reference basis for the optimal operation of the distribution system.

## 5. Conclusion

Since the reform of the electricity market, the existing researches are mainly focused on the competition of the power generation side, and few scholars have conducted in-depth exploration in the competition of the retail market of the electricity selling side. At present, there are not many and not enough researches on the impact of the electricity selling side liberalization on the distribution network.

In this paper, the power supply capacity calculation method considering the balance of interests of power selling companies is proposed. Under the background of electric power system reform, we should think systematically, follow the theme of The Times, and study the competitive environment of power supply subject, so as to make the results more practical and instructive.

## Acknowledgments

This paper is funded by the following project funds: 2018xk-A-03 Mechanical and Electronic Engineering Discipline Construction Project.

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