Research on Clearing Model of Long-Term Transaction Considering Matching Degree between Generation and Load

Zhang Lin[1,2], Zhang Qinghe[1,2], Zhang Xue[1,2], Gao Hui[1,2]

[1]Nari Group Corporation/State Grid Electric Power Research Institute Nanjing 210003 China
[2]Beijing Kedong Electric Power Control System Co., Ltd. Beijing 100194 China

Abstract. With the development of new energy and flexible load, there are many kinds of power and load characters in the power grid. It's necessary to considerate the similarity between generation output and load when it's market clearing. First, similarity analysis of generation-load curve based on the grey correlation degree is introduced, correlation between power generation enterprises and power users can be calculated. Then, market clearing model is built. market clearing mechanism is set which considering the matching degree between generation and load. The technological process of market clearing is given. Last, the effectiveness of the proposed clearing model is verified by an example.

1 Introduction

The power output and load must be balanced in real-time in the power system, and the two curves are identical in actual operation. With the incorporation of new energy and flexible load, there are many kinds of power and load characters in the power grid. So it can't improve the situation of low new energy absorption and large fluctuations of traditional units.

In order to maximize the absorption of new energy, reduce the abandonment of new energy abandonment, and ensure the smooth output of traditional units, market-oriented policies can be used, which can also coordinate the operation of power system source and load, make the curves similar between the load the new energy output. Therefore, it is necessary to consider the load demand and power generation, find a method to measure the similarity between them. A series of characteristic index can be made to express relationship between energy and load[1].

The power market price of Brazilian is calculated and determined in advance every week. There are peak, valley and normal price in the market. The working day is divided into peak, valley and normal period, and the no-working day is divided into Valley and normal period. Each period of clearing price is according to the real-time economic scheduling[2]. In the Nordic electricity spot market, the trading varieties and bidding mechanism of flexible block trading are introduced, which allows power generation and power users select to appropriate flexible blocks for trading according to their technical characteristics of power generation and the actual demand for electricity[3].

In reference [4-6], a two-way auction bidding model is established by using the bidding model of multi seller and multi buyer in regional electricity market. Reference [7] focuses on the concept and landing scheme of load curve trading from the practical point of view of the "rules for medium and long term electric power trading". The corresponding response strategies of load curve trading are put forward from three angles of power producer, power user and electricity seller respectively. Reference [8] simulates the relevant rules of the domestic monthly electricity centralized bidding market, and makes a quantitative comparative analysis of the common clearing by intersection price and by average price in the domestic monthly centralized bidding.

Currently, few documents mention the consideration of generation-load matching degree when market clearing. So the influencing factors of generation-load curve coordination is not considered. Therefore, based on the medium and long-term electricity trading mechanism, this paper introduces the generation-load matching degree as the influencing factor to study the market clearing.

2 Similarity analysis of generation-load curve based on the grey correlation degree

2.1 overview of the grey relation degree

Grey relation analysis method is a technical method based on grey theory. As a factor comparison score analysis method, It seeks the relationship among various factors in the system, finds out the main factors influencing the target value by analyzing the limited data sequence in grey system, and then analyzes the relation degree among various factors[9-11].It analyses the degree of similarity between the reference sequence and some comparative sequences, by which judges the degree of

* Zhang Lin: linlinhaoyou@163.com

correlation of the development trend of grey process. At present, the method of grey correlation analysis has been widely used in various fields.

The evaluation method of grey correlation degree has low requirements for data and is a comprehensive evaluation method with simple principle. The purpose of grey correlation analysis is to reveal the main relationship between the interrelated and influencing factors, find out the important factors that affect the target value, and make the "grey" relationship between the factors clear. As a statistical analysis theory of multi-factor comprehensive influence, grey correlation analysis curvilizes the numerical value of the analysis object and the object to be compared. The closer the curves shape are, the closer the change trend is, and the greater the correlation degree between the analysis object and the object to be compared is [12].

2.2 degree Theoretical basis of correlation analysis model

The combination model of grey correlation degree is based on the grey correlation degree analysis to determine the proportion of each single prediction model. It shows the mutual influence of factors from the quantitative. The more consistent the change trend is, the greater the correlation degree is.

Define a set of sequence $X_0^{'}$, $X_1^{'} \cdots X_1^{'}$, a new set of sequence X_0, $X_1 \ldots X_l$will be obtained after dimensionless, where X_0 is the reference sequence. All the sequence has the same time point division, which is shown as follows:

$$X_0 = \{ X_0(1),\ X_0(2),\ldots,\ X_0(m)\ ,\ldots,X_0(n)\ \} \quad (1)$$

$$X_1 = \{ X_1(1),\ X_1(2),\ldots,\ X_1(m)\ ,\ldots,X_1(n)\ \} \quad (2)$$

……

$$X_l = \{ X_l(1),\ X_l(2),\ldots,\ X_l(m)\ ,\ldots,X_l(n)\ \} \quad (3)$$

The correlation coefficient $\lambda_i(k)$ between $X_i(k)$ and $X_0(k)$at k time is:

$$\lambda_i(k) = \frac{\min(\Delta i(\min)) + \rho \max(\Delta i(\max))}{|X_0(k) - X_i(k)| + \rho \max(\Delta i(\max))} \quad (4)$$

In formula (4), $\min(\Delta i(\min)) = \min(\min(|X_0(k) - X_i(k)|))$ represents the minimum value of the second level of X_0 and X_1; $\max(\Delta i(\max)) = \max(\max(|X_0(k) - X_i(k)|))$ represents the maximum value of the second level of X_0 and X_1; ρ represents the resolution coefficient. Th e value of ρ is generally between 0 and 1.

2.3 grey correlation analysis of power generation and load curve

The typical daily curves of generation and power users are described by 96-point curve.

The typical output of generations can be described as $P_{g1}^{'}$, $P_{g2}^{'}$, ……, $P_{gm}^{'}$.

$$P_{g1}^{'} = (P_{g1}^{'}(1), P_{g1}^{'}(2) \ldots P_{g1}^{'}(t), P_{g1}^{'}(96)) \quad (5)$$

……

$$P_{gi}^{'} = (P_{gi}^{'}(1), P_{gi}^{'}(2) \ldots P_{gi}^{'}(t), P_{gi}^{'}(96)) \quad (6)$$

$$P_{gm}^{'} = (P_{gm}^{'}(1), P_{gm}^{'}(2) \ldots P_{gm}^{'}(t), P_{gm}^{'}(96)) \quad (7)$$

The typical curves of power users can be described as $P_{d1}^{'}$, $P_{d2}^{'}$, ……, $P_{dn}^{'}$.

$$P_{d1}^{'} = (P_{d1}^{'}(1), P_{d1}^{'}(2) \ldots P_{d1}^{'}(t), P_{d1}^{'}(96)) \quad (8)$$

……

$$P_{di}^{'} = (P_{di}^{'}(1), P_{di}^{'}(2) \ldots P_{di}^{'}(t), P_{di}^{'}(96)) \quad (9)$$

$$P_{dn}^{'} = (P_{dn}^{'}(1), P_{dn}^{'}(2) \ldots P_{dn}^{'}(t), P_{dn}^{'}(96)) \quad (10)$$

The dimensionless curves can be obtained through dividing each electric power of generation and load divided by its 96 point average value.

Through formula (1) - (4), the correlation coefficient between each power generation output curve and power consumption load curve is calculated. The correlation coefficient matrix λ is as follow:

$$\lambda = \begin{vmatrix} \lambda_{11} & \lambda_{12} & \ldots & \lambda_{1n} \\ \lambda_{21} & \lambda_{22} & \ldots & \lambda_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ \lambda_{m1} & \lambda_{m2} & \ldots & \lambda_{mn} \end{vmatrix} \quad (11)$$

In formula (11), λ_{mn} is the correlation coefficient between them-th generation and the n-th power user.

3 Research on market clearing model considering similarity

3.1 market mechanism

The market bidding mechanism constructed in this paper is based on the traditional medium and long-term power market (such as 'two-way bidding, centralized bidding, price difference pair pricing'), and adopts the organization mode of 'two-way bidding, centralized bidding, price difference pair pricing, and distribution collaboration'.

Under certain constraints (such as system constraints, unit constraints, transaction constraints, etc.), power generation companies rank according to the declared price from low to high, power users / power selling companies rank according to the declared price from high to low. The clearing price is the average price of the declared price of the transaction pair. When the declared price is the same, the generation and power user with high correlation coefficient have priority in transaction.

3.2 market mechanism

3.2.1 objective function

The goal of power trade is to maximize social welfare and coordinate generation-load power. Its objective function is as follows:

$$F_1 = \max \sum \lambda (P_{ui} - P_{fi}) \quad (12)$$

In formula (12), λ is the correlation coefficient of generation-load curve of trade pair; P_{ui} presents the declared price of the power user; P_{fi} presents the declared price of the generator.

3.2.2 constraint conditions

1. Balance of power generation and consumption constraint

The electricity purchased is equal to the electricity sold:

$$\sum_{j\in c,} Q_j = \sum_{j\in c} Q_i \tag{13}$$

2. market clearing

(1) According to the declared price, Generations are ranked from low to high, and power users are ranked from high to low.

$$P_j > P_{j+1} \tag{14}$$

$$P_i < P_{i+1} \tag{15}$$

(2) Suppose that the corresponding market subject of the m-th trade pair are *M*-th generation and *N*-th power user. It is assumed that the closest and lower than *M* is *M*+1, and the closest and higher than *N* is *N*+1. The next trade pair (m+1)-th are:

$$(m+1) = \begin{cases} M+1, N & \sum_{i=1}^{m} Q_{ui} < \sum_{i=1}^{m} Q_{fi} \\ M, N+1 & \sum_{i=1}^{m} Q_{ui} > \sum_{i=1}^{m} Q_{fi} \end{cases} \tag{16}$$

(3) The clearing price of m-th trade is

$$P_{\mathrm{mc}} = \frac{P_M + P_N}{2} \tag{17}$$

(4) Only when the price of electricity sale on the generation side is no more than the market marginal price can the bid be won, and only when the price of electricity purchase on the user side is no less than the market marginal price can the bid be won.

$$P_j \geq P_c \tag{18}$$

$$P_i \leq P_c \tag{19}$$

3. Coordination of Generation and load constraint

When the declared price is the same, the generation and power user with high correlation coefficient have priority in transaction.

$$Q = \begin{cases} Q_j & \lambda_{ij} \succ \lambda_{i(j-1)} \\ \frac{1}{2}Q_j, \frac{1}{2}Q_i & \lambda_{ij} = \lambda_{i(j-1)} \\ Q_{j-1} & \lambda_{ij} \prec \lambda_{i(j-1)} \end{cases} \tag{20}$$

3.2.3 collaboration degree index

Collaboration degree *K* is the difference ratio calculated by the correlation degree analysis model and the traditional clearing model,

$$K = \frac{\sum_{1}^{s_1} \lambda_{ij} Q_C - \sum_{1}^{s_2} \lambda Q_C}{\sum_{1}^{s_2} \lambda Q_C} \tag{21}$$

In formula (21),λ_{ij} is the correlation coefficient of generation-load curve of trade pair; Q_C presents trade quantity of trade pair *C;* S_1 indicates the clearing scene of 'two-way quotation, centralized bidding, price difference pricing, and distribution collaboration'; S_2 indicates the clearing scene of 'two-way quotation, centralized bidding, price difference pricing'.

3.2.4 Technological process

Technological process picture is showed as follow:

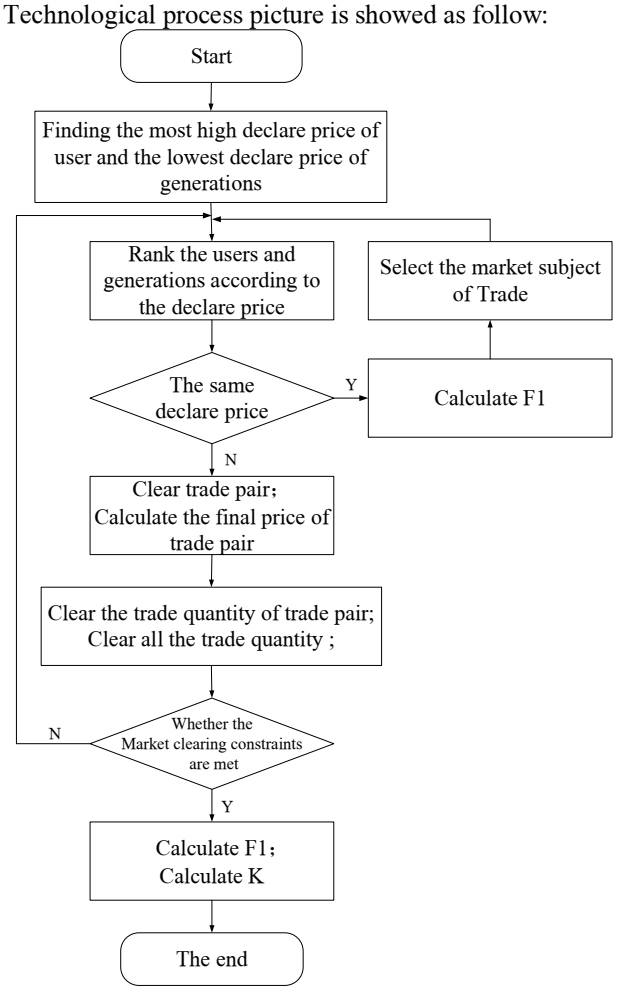

Fig. 1. Technological process.

4 Example analysis

In this paper, the scenario of monthly centralized power trade in the medium and long term is simulated. Four power generation enterprises and six power users participate in the market-oriented trading. The declaration is as table 1 and table 2:

Table 2. Formatting sections, subsections and subsubsections

Table 1. Power users declare information

unit: MWh RMB/ MWh

users	user1	user 2	user 3	user4	user 5	user 6
declare quantity	2.413	1.950	2.336	1.438	2.380	1.650
declare price	395	388	410	392	395	405

Table 2. power generations declare information

unit: MWh RMB/ MWh

generation	generation1	generation2	generation3	generation4
Declare quantity	3.240	4.160	3.792	3.408
Declare price	388	386	385	388

In this paper, Matlab simulation is used to carry out dimensionless typical daily curves of generation enterprises and power users, as shown in Figure 2 and Figure 3:

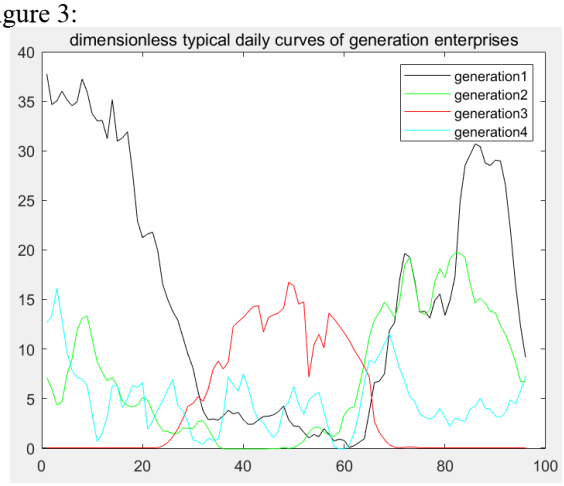

Fig. 2. dimensionless typical daily curves of generation enterprises

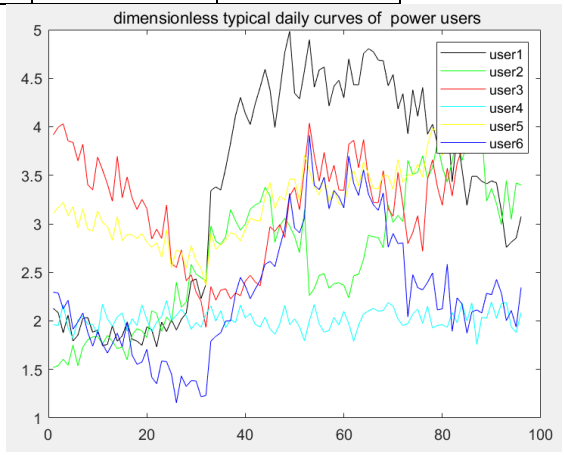

Fig. 3. dimensionless typical daily curves of power users

In order to reduce the influence of the maximum value on the correlation coefficient, the value of resolution coefficient is 0.2. By using formula (1) - formula (11), the correlation coefficient is obtained as follows:

Table 3. Correlation coefficient between generation users

	generation1	generation2	generation3	generation4
user 1	0.359	0.4021	0.4311	0.5618
user 2	0.384	0.4152	0.4009	0.5433
user 3	0.433	0.4147	0.3735	0.5925
user 4	0.412	0.4043	0.3886	0.6044
user 5	0.407	0.4153	0.3805	0.5762
user 6	0.388	0.4131	0.4137	0.5830

Through the model, we can get the value of F1=39.1929. The optimal clearing result is shown in the table-4:

Table 4. Clearing result

number	final quantity	final price	generations	users
1	2.336	397.5	generation 3	users 3
2	1.456	395	generation 3	users 6
3	0.194	395.5	generation 2	users 6
4	2.380	390.5	generation 2	users 5
5	1.586	390.5	generation 2	users 1
6	0.827	391.5	generation 4	users 1
7	1.438	390	generation 4	users 4
8	1.143	388	generation 4	users 2
9	0.807	388	generation 1	users 2

The declared prices of user 1 and 5 is the same, and that of power generation enterprises 1 and 4 is the same. Beacause $\lambda_{25}>\lambda_{21}$ and $\lambda_{42}>\lambda_{12}$, user 5 has the priority to deal with power generation enterprise 2, and power generation enterprise 4 has the priority to deal with power user 2.

Calculate the collaboration index according to equation (21), as shown in the table-5:

Table 5. collaboration index

Correlation model collaboration	Traditional model collaboration	Collaboration degree k
5.445	5.199	4.73%

In table 5 we can see collaboration degree k=4.73%, which shows that the collaboration rate of power generation and consumption can be greatly improved after considering the correlation analysis while market clearing.

5 Conclusion

There are many kinds of power and load characters in the power grid. It's necessary to make generation-load matching degree as the influencing factor to study the market clearing. Market clearing model is built. market clearing mechanism is set which considering the matching degree between generation and load. The example shows that the collaboration rate of power generation and consumption can be greatly improved after considering the correlation analysis while market clearing.

ACKNOWLEDGEMENTS

This research was supported by science and technology project of State Grid Corporation of China(item number: 52020118007D): Key technologies research and demonstration application of smart energy service system.

References

1. SHI Liangyuan, ZHOU Renjun, et al . New energy-load characteristic index based on time series similarity measurement[J]. Electric Power Automation Equipment, 2019, 39(5):75-81.
2. LIU Fang, ZHANG Lizi, et al . Brazil's electricity market research, Part I: Electricity market reform process and market trading mechanism[J]. Proceedings of the CSEE,2019, 39(1): 1-12.
3. ZENG Ming, LIU Chao, DUAN Jinhui, et al. The bilateral electricity market modes of typical countries and our reference from America and Nordic[J]. East China Electric Power, 2013,41(1):5-10.
4. SHANG Jincheng, ZHANG Zhaofeng, HAN Gang. Study on transaction model and mechanism of competitive regional electricity market: Part one ransaction model and mechanism, participation mode for hydro electricity participants and power system security checking mechanism[J]. Automation of electric Power Systems, 2005, 29(12): 7-14.
5. GMEZT, ROMANS, VAZQUEZ M C. The Spanish day ahead energy market[R/OL].[2017-04-12].http://iit.upco.es.
6. YANG Yan, ZHANG Yao, CHEN Haoyong, et al. Electricity market equilibrium model considering uncertainty of system operation[J]. Power System Technology,2012,36(7):100-105.
7. ZHANG Shuwei. The successful standard and power of electric power system reform— Discussion based on Article 9[J]. Energy,2015(4):92-96.
8. JING Zhaoxia, ZHU Jisong. Simulation experiment analysis on market rules for monthly centralized bidding. Automation of electric Power Systems,2017,41(24):42-48.
9. NIU Dongxiao, CAO Shuhua, ZHAO Lei, et al. Load forecasting technology and application [M]. Beijing: China Electric Power Press, 1998.
10. ZHANG Shaoliang, ZHANG Guoliang. Comparison between computation models of grey interconnection degree and analysis on their shortages [J]. SystemsEngineering,1996, 14 (3) :45-49.
11. SUN Caizhi, SONG Yantao. Theory discussion about grey interconnect degree model [J]. WorldGeology, 2000, 19 (3): 248- 252.
12. SHEN Maoxing, XUE Xifeng, ZHANG Xiaoshui. Determination of discrimination coefficient in grey incidence analysis [J]. Journal of Air Force Engineering University,2003,4 (1) :68-70.