Grid-connected Consumption Model of Clean Energy Power Generation Based on Digital Drive

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Abstract: The traditional cross-provincial and regional power trading mechanism can hardly meet the growing demand for clean energy consumption in China. The paper proposes a inter-provincial trading path based on the digital-driven cross-regional power trading and consumption, and establishes a cross-regional market trading model to support the large-scale consumption of clean energy. The analysis results show that the cross-regional trading market mechanism and trading model can adapt to the demand for clean energy consumption in China and increase the proportion of clean energy consumption across regions.

Keywords: Digitization; clean energy; consumption path; clearing

1. Introduction

At present, the high proportion of new energy in the network consumption faces "double high" and "double peak" characteristics, power system operation mechanism and control mode will be a profound change. With the continuous development of digital concept, digital active grid has high reliability power supply capability, flexible regulation capability and regional source-load efficient balance capability[1], strong adaptability to distributed energy sources, and is the most favorable for promoting multi-energy complimentary, which is the best carrier for building a new power system, and provides a practical path for building a new city-level power system demonstration with deep interaction between source, network, load and storage, and synergistic utilization of multiple energy sources centered on electricity[2].

At present, China's scenery renewable energy installation is mainly concentrated in the northwest, and the geographic distribution of the load center in the central and eastern part of the country has produced a serious mismatch, which brings a huge challenge for China's renewable energy consumption, and the combination of cross-province and cross-region consumption mode and effective market mechanism is an important path to support the high proportion of renewable energy consumption [3]. At present, China has initially established a inter-provincial electricity market framework, and the trading varieties, price mechanisms and trading methods have been basically standardized [4]. However, wind power, photovoltaic and other renewable energy sources will face higher risk of deviation assessment due to the intermittent and uncertainty of their power output, therefore, the declared price in power trading is usually not dominant[5]. China's current inter-provincial trading mechanism is only sorted out by the declared price of each market subject, and the market competitiveness of renewable energy is weak, which is difficult to support the demand for renewable energy consumption [6].

This paper optimizes the clearing method of inter-provincial power trading by constructing a grid-connected consumption model of clean energy power generation based on digital drive, and analyzes the results of inter-provincial trading under different trading mechanisms by comparing the arithmetic examples, which proves the effective supporting role of the inter-provincial trading mechanism proposed in this paper for the consumption of clean energy.

2. Model construction

Assuming that there are n conventional units and m renewable energy units in the sending end area, the incentive adjustment is first made to the conventional unit offer, and the trading priority is determined jointly with the

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renewable energy unit offer in the order of lowest to highest. Based on the evaluated carbon emission levels of the generating units in the sending end region, the carbon emission levels of the various types of units participating in the transaction are compared. For the unit whose carbon emission level is lower than the regional average carbon emission level, the quotation is not revised; if the carbon emission level is higher than the regional average power generation carbon emission level, the unit quotation is corrected to encourage low-emission units to preferentially participate in inter-provincial delivery:

$$C = \min \sum_{i=1}^{I} P_i Q_i \tag{1}$$

$$E_c = \frac{\sum_{i=1}^{n} \varphi_i Q_i^c + \sum_{i=1}^{m} Q_i^k}{\sum_{i=1}^{n} Q_i^c + \sum_{i=1}^{m} Q_i^k} \tag{2}$$

$$\alpha_i = \varphi_i / T_c = \max\{1, \quad \alpha_i\} \tag{3}$$

$$P_i = \alpha_i p_i \tag{4}$$

Where C represents the cost of power purchase in the affected area; I represents the number of winning units; Q_i represents the declared trading volume of winning units; E_c represents the average carbon emission of units in the sending end area; φ_i represents the carbon emission coefficient of conventional units; Q_i^c represents the declared trading power of conventional units; Q_i^k represents the declared trading power of clean energy units; α_i represents the adjustment coefficient of unit offer; p_i represents the declared trading price of units; P_i represents the adjusted ranking price of units.

Five main constraints are considered, including cross-regional contact line transmission power constraint, power balance constraint, clean energy consumption quota constraint at the sending area, power generation constraint at the sending area, and unit declared power constraint, as follows.

$$0 \le \sum_{i=1}^{I} G_i^t \le \left(G_l^{\max} - G_l^t\right) \tag{5}$$

$$\sum_{i=1}^{I} Q_i = Q_d \tag{6}$$

$$Q_s^k \ge T_s^k \tag{7}$$

$$Q_{i,\min} \le Q_{i,z} \le Q_{i,\max} \tag{8}$$

$$Q_{i,z} \le Q_i \tag{9}$$

Where, G_i^t represents the outgoing power of the unit; $G_l^{\max}$ represents the maximum power that can be carried by the inter-regional contact line; G_l^t represents the agreed occupied capacity of the inter-regional contact line; Q_d represents the demand power of the receiving end; Q_s^k represents the clean energy consumption of the sending region; T_s^k represents the clean energy consumption quota of the sending region; $Q_{i,\min}$, $Q_{i,z}$ and $Q_{i,\max}$ represents the lower limit of output, the winning power generation and the upper limit of output of the indicated unit respectively.

3. Example analysis

3.1 Original data

This paper carries out arithmetic simulation analysis based on China's northwest-central-south DC operation data,

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and collects G province-H province operation data, as well as power load, generation curve, installation situation, and market transactions, among which the installed power of G province is shown in Table 1.

Table 1 G Province's power supply structure

TYPE	INSTALLED CAPACITY/MW	PROPORTION OF INSTALLED CAPACITY/%
Coal combustion	22000	43
Wind Power	12000	23
Photovoltaic	8000	16
Hydroelectric	9500	18

Using the consumption model constructed in this paper, two trading scenarios are set up for clearing respectively.
1) Scenario 1: traditional cross-regional power clearing method.
2) Scenario 2: optimize the clearing method and adjust the quotation of the power producer.

It is assumed that the annual electricity demand of province H is 3.5 million MWh, while the subjects participating in power trading in the sending end region include five conventional power generators and five clean energy power generators, and the specific parameters are shown in Table 2.

Table 2 Parameters of generator set trading market

SERIAL NUMBER	UNIT TYPE	INSTALLED CAPACITY/MW	DECLARED POWER/TEN THOUSAND MWH	DECLARED ELECTRICITY PRICE/YUAN/MWH	CARBON EMISSION COEFFICIENT
1	Coal-fired unit 1	1000	40	317.2	0.95
2	Coal-fired unit 2	1500	60	313.2	1.02
3	Coal-fired unit 3	1300	70	315.2	0.98
4	Coal-fired unit 4	1800	65	311.1	1.01
5	Coal-fired unit 5	1000	30	309.1	1.03
6	Photovoltaic 1	800	15	335.2	0
7	Photovoltaic 2	1200	17	325.3	0
8	Wind Power 1	1000	35	323.8	0
9	Wind Power 2	800	30	330.1	0
10	Hydroelectric	1500	50	285.3	0

3.2 Analysis of results

(1) Scene 1

In the base scenario 1, the result is shown in Figure 1 as it is cleared exactly by the declared price ordering of the market players.

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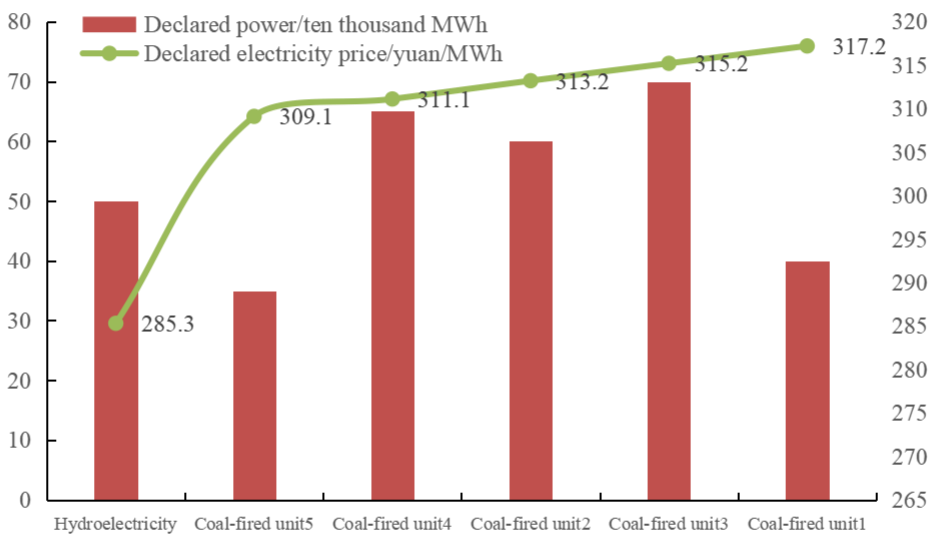

Figure 1 Scenario 1 Clearance results

As can be seen from Figure 1, hydropower was given priority in the transaction, the other transactions were all coal-fired units, wind power and photovoltaic units were all unsuccessful, and the clearance price was RMB 317.2/MWh, which is just the declared price of coal-fired unit 1.

(2) Scene 2

In Scenario 2, the average carbon emission of Gansu declared units is 0.535, and the quotation of each unit is adjusted according to the clearing rules proposed in this paper according to its carbon emission intensity. The adjustment coefficient and adjustment ranking price of each declared unit quotation are shown in Table 3. According to the adjusted price, the clearing results are shown in Figure 2.

Table 3 Price adjustment coefficient and adjusted prices of declared units

SERIAL NUMBER	UNIT TYPE	DECLARATION PRICE/YUAN/MWH	ADJUSTMENT COEFFICIENT	ADJUSTED PRICE/YUAN/MWH
1	Coal-fired unit1	317.2	1.77	561.444
2	Coal-fired unit 2	313.2	1.92	601.344
3	Coal-fired unit 3	315.2	1.81	570.512
4	Coal-fired unit 4	311.1	1.91	594.201
5	Coal-fired unit 5	309.1	1.93	596.563
6	Photovoltaic 1	335.2	1	335.2
7	Photovoltaic 2	325.3	1	325.3
8	Wind Power 1	323.8	1	323.8
9	Wind Power 2	330.1	1	330.1
10	Hydroelectric	285.3	1	285.3

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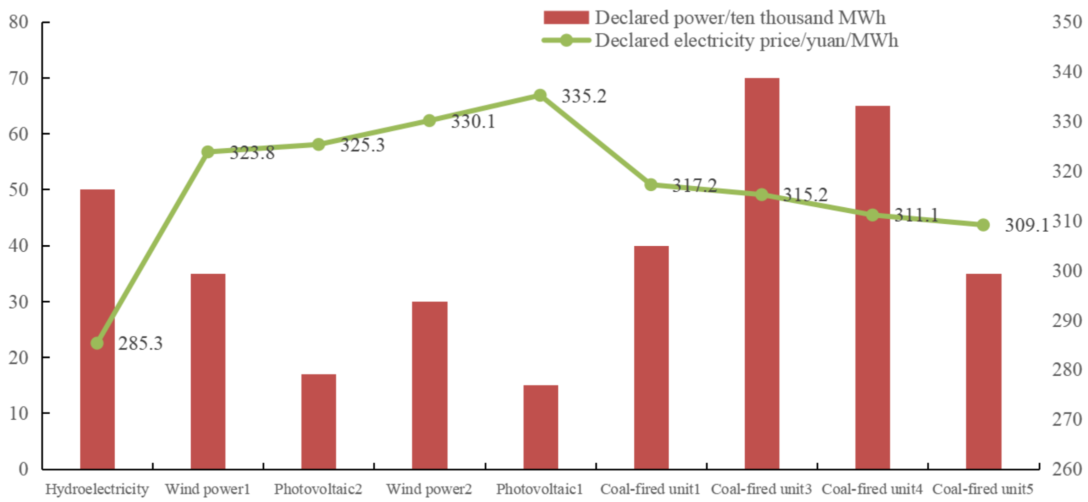

Figure 2 Scenario 2 Clearance results

It can be seen from Figure 2, in the clearing results obtained based on the adjustment of the declared price, clean energy is basically declared successfully, and the clearing price is 335.2 Yuan/MWh. Applying the clearing method of power trading proposed in this paper, renewable energy units are given priority in clearing, and thermal power units with relatively lower declared price and lower carbon emission factor are more likely to win the bidding than other thermal power units. Due to the environmental benefits of renewable energy, when renewable energy power is sent out, it can reduce the carbon emission pressure due to power generation in the receiving end area, thus reducing the abatement cost in the receiving end area and spreading the abatement cost to receive external renewable energy power, so the clearance price is improved compared to the traditional clearance method.

4. Conclusion

China's power system renewable energy installed capacity has increased significantly, due to the power generation and electricity consumption space is not synchronized, renewable energy is difficult to consume locally, while the high load area power supply capacity is difficult to meet local demand. The inter-provincial power trading to support renewable energy consumption is essentially an optimization of the traditional inter-provincial power trading mechanism. The environmental benefits of renewable energy units will be reflected in the process of trading out, supporting renewable energy to participate in inter-provincial power trading on a priority basis, and enhancing the competitiveness of renewable energy market-based trading.

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References

1. Li Haihai, Huang Yanshuo. Can digital development contribute to the goal of carbon neutrality? --An empirical analysis based on urban panel data [J]. Journal of Xiangtan University (Philosophy and Social Science Edition), 2023,47(01):30-36.
2. Chen Sheng, Wei Zhinong, Gu Wei, et al. Carbon neutral oriented transition and revolution of energy systems: multi-energy flow coordination technology[J]. Electric Power Automation Equipment, 2021, 41(9):3- 12.
3. Xia Qing, Chen Qixin, Xie Kai, et al. Key issues of national unified electricity market with Chinese characteristics (1): enlightenment, comparison and suggestions from foreign countries [J]. Power System Technology, 2020,44(08):2801－2808.
4. Xu Zhe, Ding Junce, Liang Zhifei, et al. Realization mode of medium- and long-term inter-provincial

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continuous transaction mechanism[J]. Power System Technology, 2020,44(06):2071－2077.

5. Liu Shuo, Li Guodong, Zhang Shengnan, Xu Liang, Xing Tong, Yang Qiaoyin, Liang Shaowei. Research on cross-provincial trading mechanism and trading model under high percentage clean energy access [J]. Modern Electricity, 2022,39(06):659-667.
6. Wang Hui, Chen Bobo, Liao Kun. Bi-optimal model for trans-provincial power generation trading based on low-carbon incentive clearing method [J]. Renewable Energy Resources, 2019,37(12):1842－1849.

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