Research on optimal scheduling of county main new energy consumption based on internal non-cooperative game under curve transaction

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Abstract: Under the "double carbon" goal and background, new energy power generation will usher in great development. The investment and construction of new energy projects and the scale of grid connected transmission are increasing, which puts forward higher requirements for the investment decision-making management and income of county new energy subjects. Based on the power curve trading and non cooperative game theory and the day ahead real-time two-stage adjustment and correction mechanism of county subjects, this paper briefly analyzes the new energy consumption and income of county subjects based on internal non cooperative game under curve trading.

Keywords: Curve trading; Non-cooperative game; County main body; Day ahead real-time two-stage trading; new energy consumption; Income situation.

1. Introduction

In the future, the utilization of energy will develop in the direction of clean and renewable. However, the uncertainty of difficult prediction and control seriously hinders the entry of new energy into the power grid. The county main body with flexible regulation ability provides an effective way to solve the grid connected power generation of renewable energy. Due to the limitations of prediction technology at this stage, the prediction error of intermittent energy output power and user load power consumption such as county scenery is large. As the main body responsible for its own profits and losses, the county body is facing the risk of strict assessment of power market deviation. Under many uncertain factors such as market electricity price and new energy power generation, it has become a difficult problem for the county subject of market-oriented operation to flexibly use curve trading to realize the economic dispatching of internal and external power market.

2. Power curve trading mechanism

The subject matter of spot power trading has changed from the traditional index power without time and space value to the power curve with time scale. As a financial tool to avoid the risk of electricity spot price, medium and long-term contract must also reflect the time-space value of electricity price. Therefore, in the spot market environment, the curve decomposition must be carried out for medium and long-term contracts.

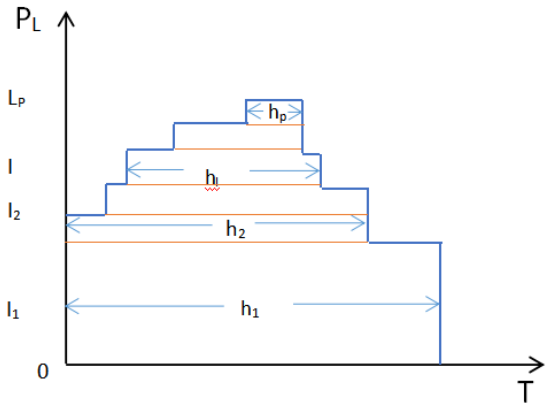

Figure 1. Block bidding mechanism

Since the production and use of electric energy have time continuity, the goods sold or purchased are "energy blocks" with a certain duration, as shown in Figure 1. Therefore, only by adding the time dimension of electric energy commodity (power curve) and considering the time dynamic characteristics of power curve can the quality of electric energy commodity be accurately measured (note that there is no contradiction between the homogenization of electric energy in physics and the heterogeneity of electric energy commodity in economics, and the latter is mainly used for commodity pricing). In

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the trading process of power market, different (horizontal or vertical) "energy blocks" are used to fill the area under the load curve to achieve power and electricity balance. In this process, prices with different connotations will also be formed.

The essence of centralized bidding transaction is a multilateral transaction, which needs to be carried out based on "standardized products" (otherwise, bidding cannot be carried out on a unified platform). It is impossible to customize the load curve. The rough way is to only bid for electricity. Because users in different industries have different typical load curves, it is difficult to implement centralized bidding according to the standard load curve. The idea of piecewise bidding (or horizontal auction) can be introduced here. In the initial stage, the load is roughly divided into base charge energy, waist charge energy and peak charge energy for bidding respectively, and further subdivided into multiple load segments (energy blocks) according to the load duration with the advancement of the market, so as to conduct centralized bidding transactions for electric energy in different load segments.

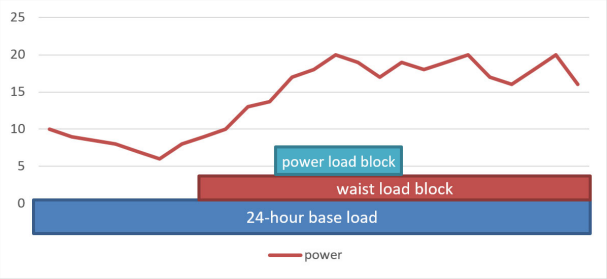

Figure 2. Centralized bidding of energy blocks with different loads

1.Annual common decomposition curve:

Determine the annual monthly power ratio (Y) and monthly daily power ratio (M) according to the historical load of unified dispatching, decompose the annual power into monthly and daily power, and then decompose the daily power into 24-hour power curve according to the daily common decomposition curve (D1, D2 or D3), that is, the annual common decomposition curve includes Y+ M + D1, Y + M+ D2 and Y + M+ D3.

2.Monthly common decomposition curve:

According to the monthly daily ratio (M), decompose the monthly contract power into daily power, and then decompose the daily power into 24-hour power curve according to the daily common decomposition curve (D1, D2 or D3), that is, the monthly common decomposition curve has three forms: M + D1, M + D2 and M + D3.

3.Weekly common decomposition curve

According to the monthly daily ratio (M), decompose the weekly power into daily power, and then decompose the daily power into 24-hour power curve according to the daily common decomposition curve (D1, D2 or D3), that is, the weekly common decomposition curve includes M + D1, M + D2 and M + D3.

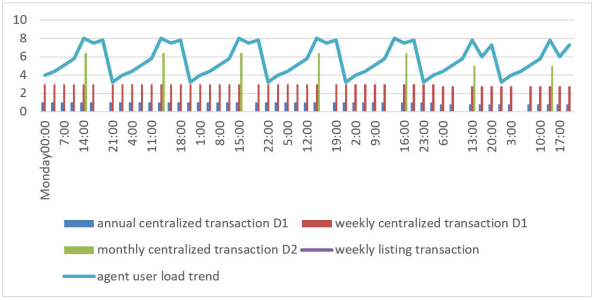

Figure 3. Long-term contract position of power sales companies

3. Non-cooperative game theory

In order to realize the internal energy optimal management of county subjects, a new regional power market framework is built, an energy management model focusing on the internal energy transaction of county subjects is proposed, and the model is solved by using the master-slave game theory. Among the county subjects, power selling users and power purchasing users are independent interest subjects. Power purchasers minimize the cost by setting a reasonable purchase price; The electricity selling users set the optimal electricity selling quantity according to the electricity purchase price proposed by the electricity purchasing users, so as to maximize their own interests. Because the power selling users need to optimize their own benefits according to the power purchase price of the power purchasing users, and the power purchasing users should put forward the most reasonable power purchase price according to the power sales of the power selling users, there is an interest game between the power purchasing users and the power selling users. As the power seller providing photovoltaic, the power selling user has the priority to decide. Therefore, the game between the power selling user and the power purchasing user can be constructed as a stark Berg master-slave game.

$$G_{CEI} = (N \cup B); p_{in}^{h}; C_{B}^{h}; W_{s_1}^{h}; \ldots; W_{s_1}^{h}; U_{s_1}^{h}; \ldots; U_{s_{N_s}}^{h}$$

Among them, the game player includes the power selling user set N (the leading Party) and the power purchasing user set B (the follower). P_{ih}^{h} is the power purchasing strategy of the power purchasing user, C_{B}^{h} is the total cost of the power purchasing user group, calculated according to equation 29; $\{W_{s_1}^{h}, \ldots, W_{s_{N_s}}^{h}\}$ is the power selling strategy set of the power selling user, from which the power selling user selects the power selling strategy, as shown in$\{w_{s_1}^{h}, \ldots, w_{s_{N_s}}^{h}\}$; $\{U_{s_1}^{h}, \ldots, U_{s_{N_s}}^{h}\}$is the revenue collection of power selling users, calculated according to equation 24.

4. Day ahead real-time two-stage transaction correction mechanism

(1) Power day ahead trading aiming at maximizing the economic benefits of county entities. As a market entity, the county entity participates in the day ahead energy transaction and formulates the optimal economic

arrangement for the next day according to the prediction of the day ahead market electricity price, user load and wind and solar power generation power. Sell electricity to the market when its own power generation is surplus and buy electricity when it is insufficient, and settle the settlement according to the clearing price of the day ahead energy market. In order to avoid the phenomenon of abandoning wind and light, this paper takes the county main body as the price receiver, and improves the consumption capacity of the system through grid connected operation. In the market-oriented operation of county main body, the goal of daily dispatching plan is to maximize the daily operation income of the system.

Among them, in the market-oriented operation of microgrid considering demand response, the goal of microgrid daily scheduling plan is to maximize the daily operation income of the system. Among them, the daily operation income of microgrid includes: transaction income with power market R_t^{LD} and power sales income to load users R_t^{MA}; The daily operation cost of microgrid includes: operation cost and start-up cost C_t^{CG} of various distributed micro generators, operation and maintenance cost M_t^{DG} of wind power and photovoltaic, depreciation cost C_t^{ES} of battery energy storage, and compensation cost P_t^{DR} of user demand side response.

$$\max R_{profit} = \sum_{t=1}^{NT}(R_t^{LD} + R_t^{MA} - C_t^{CG} - M_t^{DG} - C_t^{ES} - P_t^{DR})$$

Among them, $R_t^{LD} = \pi_t^{ret}(D_t - P_t^{LC2})\Delta T$; $R_t^{MA} = \pi_t^{DA}P_t^{DA}\Delta T$;$C_t^{CG} = \sum_{i=1}^{N_G}\left[C(P_{i.t}) + C_{i,t}^{UCD}\right]$

(2) Power real-time trading with the goal of minimizing the prediction deviation of the correction day ahead trading market. Due to the influence of prediction error, the county subject needs to constantly update the predicted values of load and wind power, and make real-time power adjustment to the daily dispatching plan. As a useful supplement to the day ahead market, real-time balancing market is an effective means to improve the system power balance by using market regulation to balance the power supply and demand deviation in the operation of power grid. Therefore, county main operators can participate in the real-time market, predict the real-time electricity price and formulate reasonable electricity trading, reduce the real-time adjustment cost and promote the consumption of intermittent energy. In the real-time market, the active output of the county main adjustable output unit takes the daily dispatching plan curve as the reference value. The real-time adjustment goal of the county main body is to minimize the real-time adjustment cost of the system.

$$\min P_{fee,t} = \sum_{j=1}^{4}(\Delta M_{t,j}^{DG} + \Delta C_{t,j}^{CG} + \Delta C_{t,j}^{ES} - \Delta R_{t,j}^{LD}) - \Delta R_t^{MA} + \Delta P_t^{DR}, \forall t = 1,2,\ldots,24$$

Among them, $\Delta R_{t,j}^{LD} = \pi_t^{ret}\left(\Delta\tilde{P}_{t,j}^{RT-LD} - P_t^{RT-LC} + P_t^{DA-LC2}\right)\Delta T$

$$\Delta R_t^{MA} = 4\pi_t^{RT}P_t^{RT}\Delta T$$

Where, for period t, π_t^{RT} represents the real-time market forecast electricity price, $\Delta\tilde{P}_{t,j}^{RT-LD}$ represents the forecast load deviation at time j (15min), P_t^{RT} represents the adjusted electricity quantity of microgrid participating in the real-time balance market, and P_t^{RT-LC} represents the reduced electricity quantity of LC user load in the real-time market.

5. Conclusion

Based on the introduction of power curve trading and non-cooperative game theory, the day ahead real-time two-stage regulation and correction mechanism of county subjects, this paper briefly analyzes the new energy consumption and main income of county subjects based on internal non cooperative game under curve trading, so as to provide reference for the follow-up county power grid under the new policy of power system reform, It has laid a theoretical foundation for further effectively promoting the consumption of new energy, adjusting the investment benefits of internal subjects and optimizing County Energy autonomy. The experimental demonstration shows that the new energy consumption mechanism of county main body based on internal non cooperative game under curve transaction proposed in this paper will effectively reduce the investment and operation cost of county main body, effectively ensure the power resource supply, promote the optimal distribution of power resources, optimize the investment benefit management, ensure the asset utilization efficiency in the county main body operation and win the market competitiveness, While ensuring the safe and stable operation of power system and power quality, improve the economic benefits of large power grid operation. In order to promote the delivery and consumption of large-scale centralized further steadily and orderly and distributed clean energy, ensure the social and environmental benefits of project investment, lay a solid foundation, and provide an important guarantee for accelerating the realization of the "double carbon" goal.

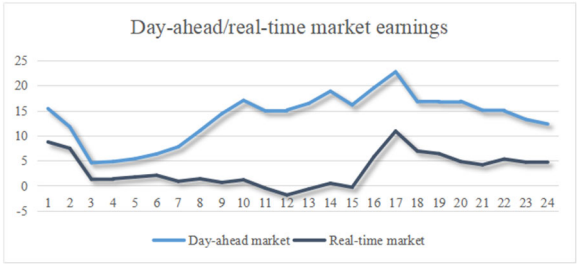

Figure 4. Day-ahead/real-time market earnings

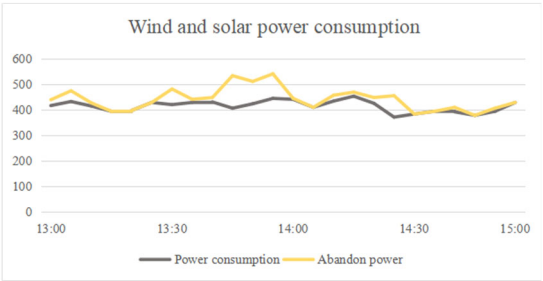

Figure 5. Wind and solar power consumption

Acknowledgments

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