Mid-and Long-term Contract Decomposition to Promote New Energy Consumption

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Abstract. With the increase in China’s new energy installed capacity, the pace of domestic power market reform is also steadily accelerating. Having the feature of randomness, volatility and intermittency which makes power generation fragmented, higher risks occur when new energy generation is involved in spot market. The proposal of a new round of electricity reform also brings great challenges for The Independent System Operator (ISO), including decomposing mid- and long-term contract curve which not only requires consideration of monthly electricity balance but also makes the curve conform with the power forecasting to the greatest extent. The Independent System Operator should formulate reasonable mid- and long-term curve decomposition combined with the signed contracts as well as ensure reasonable and fair income of new energy plants in spot market to increase their enthusiasm in the market in the process of decomposing mid- and long-term contract curve.

1. Introduction

The CPC Central Committee and the State Council officially issued the bill ‘Several Opinions on Further Deepening the Reform in System of Electricity Organization’ in March, 2015, which marked the new step of Chinese electricity market development. Announced by the bill ‘the Notifications of starting the establishments of electricity market in pilot areas’, the establishments of electricity market have been launched in eight pilot areas, including the south China (start from Guangzhou), west Inner Mongolia, Zhejiang, Shanxi, Shandong, Fujian, Sichuan, and Gansu. The test run of the West Inner Mongolia simulated electricity market began at June 26th, 2019, which announced all the work for electricity market establishment had been accomplished in all eight pilot areas, including formulating regulations and test runs of spot market.

Based on abundant wind and solar resources, the new energy generation has been growing rapidly in the North-west China. The total amount of capacity in Gansu was 50,790MW in the end of 2018, and the new energy capacity was 20,880MW, which occupied 41% of the total capacity and became the main source of energy. The reform in electricity market finds a new way to solve the new energy consumption problem. However, the new energy holds the characteristics of randomness, variability, and intermittent, leading to a more severe ‘fragmented generation’ situation in the new energy generation highly-integrated areas. The risk for new energy generation is pretty high if it participates in the spot market, which is due to the inequality between generation capability and generation capacity. Therefore, the mid-and long-term contract decomposition regulations are needed, in order to build the
linkage between the mid-and long-term trade and spot trade, and guarantee the reasonable interest of new energy generation in the spot market.

Therefore, based on the high-proportion of new energy and newly established electricity market in Gansu, this paper proposes a mid-and long-term contract decomposition model, which coordinates the interest of new energy generation, new energy generation forecast, and the requirements on the equilibrium of propelling contract. The decomposition on the new energy generation also ensures the interest of new energy generation to be reasonable and equitable, and provides a power support for the establishment of electricity market.

2. Gansu Electricity Spot Market Program
Gansu has started the test run of electricity spot market within itself in December 28th 2018, which holds the core of ‘power balance’, and includes the unilateral competition in the generation side. The effort on market solves the contradiction between generation and consumption existing in Gansu electricity industry, as well as solving the problem of ‘squander wind and solar’.

Gansu electricity market holds three-step settlement, including the settlements for mid-and long-term contract, day-ahead market and real-time market. For the first step, the prices of mid-and long-term contracts are stated in the contracts. The second step settlement accounts the amount difference between the day-ahead market forecast amount and mid-and long-term contracts decomposed amount. The third step settlement accounts the amount difference between the real-time market consumed amount and day-ahead market forecast amount. Since the settlement account can affect the interest of market participants, the mid-and long-term contracts decomposition needs to fully consider the situation of the whole area, as well as considering the reasonable interest of all types of generation.

The day-ahead market clear curve can be gained from security constraint unit commitment and security constraint economic dispatch. The actual contribution curve of generators can be gained from the data from TMR system. Since the uncertainty and variability of new energy, it cannot be controlled as coal generators, thus lack of competition capability in the market. Therefore, the mid-and long-term contracts from new energy generation just include the contract amount. Since there is no settlement curve for new energy generation, the system operator needs to fully consider the demand forecasting, linking-up road planning and new energy forecasting, and decompose the generation based on resources types. The decomposition method would severely affect the interest of new energy generation, as well as the enthusiasm of market participation.

3. New Energy Mid- and Long- term Contracts Decomposition Model

3.1. Objective Function
This model treats the new energy mid-and long-term contracts decomposition as an optimal problem. The optimized objective is to achieve the equilibrium on all mid-and long-term contracts.

$$\min_{i=1}^{N} (F_i + \alpha_i C_i)$$

where $F_i$ is the electricity difference for generator $i$, $C_i$ is the economic cost for generator $i$, $\alpha_i$ is the reference ratio of economic indicators.

3.2. Constraints
Since the estimation for electricity amount generated by each new energy generator needs to be done for each day, the time span for the optimization model should be current hour to the end of the day. In the meantime, the constraints need to consider the day-ahead forecasting of new energy generation.

3.2.1. Power Balance Constraint

$$\sum_{i=1}^{N} P_{i,t} - D_t = 0, t \in TD$$
where $P_{i,t}$ is the output of generator $i$ in time $t$, and $D_t$ is the demand forecast in time $t$.

3.2.2. Power Amount Constraint

$$\frac{1}{4} \sum_{i=1}^{N} P_{i,t} - Q_{i,N} - d_{i}^{\text{up}} + d_{i}^{\text{down}} = 0, d_{i}^{\text{up}}, d_{i}^{\text{down}} \geq 0$$

(3)

where $Q_{i,N}$ is the power generation control target in time $t_N$ to $T$ for generator $i$, equaling to generation control target minus the sum of the output from 0 to $t_N-1$, $d_{i}^{\text{up}}, d_{i}^{\text{down}}$ are the upper and lower bound for output difference.

3.2.3. New Energy Forecast Constraint

$$P_{i,t}^{\text{min}} \leq P_{i,t} \leq P_{i,t}^{\text{max}}, t \in TD$$

(4)

where $P_{i,t}$ is the power output for generator $i$ in time $t$. $P_{i,t}^{\text{min}}$ and $P_{i,t}^{\text{max}}$ are the forecasting power output limits for generator $i$ in time $t$.

3.2.4. Line Capacity Constraint

The model uses the DC power flow model, and the line capacity limits constraints are as follows:

$$-f_{l}^{\text{max}} \leq \sum_{i=1}^{N} P_{i,t} G_{i,l} - \sum_{i=1}^{N} D_{j,t} G_{i,j} \leq f_{l}^{\text{max}}$$

(5)

where $G_{i,l}$ is the element in row $l$ and column $i$ of power shift factor matrix $G$. $D_{j,t}$ is the demand forecast for node $j$ in time $t$. $f_{l}^{\text{max}}$ is the line capacity limits for line $l$.

4. The Decomposition Procedures for New Energy Mid-and Long-term Contracts Based on Completion Equilibrium

Since the location difference of new energy generator, the output forecast for each generator cannot be identical. Fully considering the short-time forecast of new energy generator, the decomposition procedures contains four steps: power iterative computation, new energy forecasting, model establishing and model solving.
5. Case Study

This model is tested on a modified IEEE 39 bus system, with the generators substituted by actual Gansu generator data on June 2019, including 5 wind generators, 3 solar generators and 2 coal generators. The mid-and long-term contracts of the 10 generators are also engaged into the model, which is used to test the procedure mentioned above.

The case study, as well as made a comparison of interest for generators, for both under mid-and long-term contracts standard computational model, and under new energy output forecasting model.

5.1. Results for mid- and long-term contract decomposition

Based on the actual output and demand data from Gansu power grid, the case study computed the demand on each bus. Combined with the power output limits constraints based on output forecasting of
new energy generators, power control constraints based on contract completion equilibrium, and power balance constraints, the optimal power output of the 10 generators can be gained for the whole 24-hour time span, and shown in the figure below:

![Figure 2. New energy mid- and long-term contract curve decomposition method](image1)

where the violet curve represents the forecast demand, and other curves represent the generation output values for generators.

The standard curve for wind and solar generation are as follows:

![Figure 3. Standard power output curve for wind and solar generation.](image2)

Wind power output is greatly affected by the weather. Due to the randomness and volatility of wind power, the daily average equivalent utilization hours of a single wind turbine group varies widely. Figure 3 uses the typical wind power generation to predict the curve texture. It can be seen that the wind turbine is in a state of fluctuation with the wind power output in a day.
Due to lower Solar Energy price, the wind power output will have a low point when the sunshine time is strong and solar energy unit generates the maximum time of 12-18 points. Because the solar energy price is lower, the output of the wind power turbines are squeezed.

5.2. Analysis of the income of the new energy field in the electricity market
Since the mid- and long-term trading curve is a financial contract, it is only used in the settlement process. Generally, the mid- and long-term contract decomposition is carried out in the order of year, month, month, and day, and the daily time is based on the standardized contract curve. Decomposed, and the daily battery is fixed without rolling calculation.

The comparison of the standard medium- and long-term curve decomposition method and the medium- and long-term curve decomposition method considering the progress balance and the new energy output prediction are shown in Figure 5.

As can be seen from Figure 5, according to the standard mid-and long-term curve decomposition, when the wind power is small, when the power of the curve is not resolved, it is necessary to purchase electricity from the spot market to meet the mid- and long-term contract power. According to the actual me- and long-term contract signed by a power plant and the clearing price of the spot market, the
6. Conclusion

Based on short-term forecast of new energy, this paper built a mid- and long-term contract decomposition model, which can match the generation forecast with new energy contract, and reach out the goal of contract completion equilibrium. Based on the result from case study, the method proposed above can coordinate new energy forecasting and new energy interest, which provides a powerful support for linking mid-and long-term trade and spot market.

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