Spot trading strategy considering multiple constraints for electricity retailers

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Abstract. In order to solve the inert trading and irrational trading of electricity retailers in the spot market trading environment, increase the income of electricity retailers and reduce transaction risk, a spot trading strategy considering multiple constraints for electricity retailers is proposed. Similar days are selected by analyzing the date type and the temperature difference of the spot market trading day, on the basis of similar days, the electricity consumption information of electricity retailers’ agent users, day-ahead and real-time electricity price of sport trading market are predicted, combing the user-side excess profit recovery fee, mid-to-long term shortage recovery fee and mid-to-long term curve deviation recovery fee restrictions in Shanxi Province spot trading rules, optimize the mid-to-long term daily 96 points daily electricity purchase curve and day-ahead 96 points daily electricity biding curve, and use the real data of Shanxi spot market transactions to calculate the multi-day income of the electricity retailers to verify the practicability of the spot trading strategies.

Keywords: Electricity retailers, spot trading, multiple constraints.

1. Introduction

Since the release of document No. 9 in 2015, the reform of electricity selling side has been gradually deepened, and electricity selling companies have joined the electricity market as market players. As a bridge between the wholesale market and retail market, to undertake, electricity sales companies bear uncertain risks such as market price, proxy user load change uncertainty risk. Especially with the gradual development of the domestic spot market in pilot provinces, how to configure reasonable trading strategies for electricity retailers and effectively avoid market risks has become the core issue of its operations. Literature [3] introduces the skewness into the power purchase portfolio optimization model, and uses an improved weighted conditional risk value as the risk measurement index. Literature [4] uses interval numbers to describes the uncertainty of power demand and electricity price, and simulates the impact of load adjustment and load transfer behavior on electricity sales companies, and solves the power purchase portfolio optimization problem of power retailers by using the linear programming model of enhanced curve. Literature [5] proposed an optimal power purchase strategy model consisting of a med-term decision model and a short-term decision model. Literature [6] studies the volatility, periodicity, mean recovery and other characteristics of spot price, and conducts spot...
trading according to the electricity price. In this paper, similar days are selected by date type and temperature, an on the basis of the similar day, combined with constraint conditions such as deviation recovery in spot trading rules, a spot trading strategy considering multiple constraints for electricity retailers is formulated, and compared the inertia and irrational transactions of the original electricity retailers, it can obtain relatively stable income for electricity retailers and reduce transaction risk.

2. Data Selection
Since the spot pilot provinces have not been carrying out spot transactions for a long time, the selection of similar days in this paper is mainly based on the date type and temperature to determine the similar days. The date types are divided into working days, rest days and holidays. If the highest temperature and lowest temperature of the same date type are the same, it will be judged as similar days.

Obtain the historical electricity consumption information and spot trading day-ahead and real-time electricity price information of the power sales company’s agents users from the trading center, and predict the user’s future electricity consumption and spot market day-ahead and real-time electricity prices. The basic value of data required for user electricity consumption and spot trading day-ahead and real-time electricity price forecasting is selected according to the following rules: If the date type is different, historical electricity price data of nearly 30 trading days is selected as the base value; If the date type is the same and the highest and lowest temperatures are not consistent, the historical electricity price data of nearly 30 trading days of the same date type is selected as the basic value. If the date type is the same and the highest and lowest temperatures are the same, the similar daily historical electricity price data will be used as the base value. Based on the data of historical electricity price, the day-ahead and real-time electricity price of the future electricity consumption and spot market of the agent users of the electricity selling company is predicted.

3. Conditional Constraint
In order to reduce the risk of market price fluctuations and reduce the speculative mentality of market participants, all the pilot provinces of spot trading have made corresponding constraints on the allowable range of electric quantity deviation on the user side of the spot electric energy market, and recovered the earnings of spot electric energy beyond the allowable range of deviation. The latest edition of Shanxi Province Power Market Rules Compilation (Trial Operation V7.0) [7], the cost recovery on the user side mainly includes the excess profit recovery cost, the mid-to-long term shortage recovery cost and the mid-to-long term curve deviation recovery cost.

3.1. Excess profit recovery expense on the user
If the time-of-use deviation quantity in the real-time market of the user side exceeds the allowable deviation range, the profit of the difference between the time-of-use price in the real-time market and the day-ahead market beyond the allowable deviation shall be included in the treatment of the market operation cost.

3.2. Mid-to-long term deficiency recovery
For the profit space of the total amount of the mid-to-long term contracts on the user side is less than 95% of the total daily electricity consumption, the difference between the maximum price of the mid-to-long term contracts on the day of the provincial power market and the average daily price of the spot real-time market shall be deducted on a daily basis, and the relevant funds shall be included in the operation cost of the power generation side market.

3.3. Uses mid-to-long term curve deviation recovery costs
The regulation on recovery cost of mid-to-long term curve deviation for the hourly power consumption of mid-to-long term transaction contract and actual power consumption on the user side exceeds the allowable deviation range, the excess power shall be recovered in accordance with the
highest and lowest price difference at the unified settlement point on the user side of the day-ahead market, and the recovery cost shall be included in the market operation cost on both sides of the issue.

4. Strategy Analysis

4.1. Price data preparation

This section mainly analyzes the historical day-ahead, mid-to-long term spreads and real-time day-ahead spreads. By using the method of similar day selection above, historical data records of n similar days are selected to obtain the daily, daily and real-time price information of power spot trading history, 15min/point, namely 96 points per day.

The price information of 96 points before the history of n groups is \( \{P_{\text{day-ahead}}, P_{\text{day-ahead,2}}, \ldots, P_{\text{day-ahead,96}}\}, \ldots, \{P_{\text{day-ahead}}, P_{\text{day-ahead,2}}, \ldots, P_{\text{day-ahead,96}}\} \), and the price information of 96 points before the history of n groups is \( \{P_{\text{real-time}}, P_{\text{real-time,2}}, P_{\text{real-time,96}}\}, \ldots, \{P_{\text{real-time}}, P_{\text{real-time,2}}, \ldots, P_{\text{real-time,96}}\} \).

Then day-ahead 96 point time price is \( P_{\text{day-ahead}} = \frac{\sum_{m=1}^{n} P_{\text{day-ahead,m,i}}}{n}, \ i = 1,2,\ldots, 96 \). Real-time 96 point time price is \( P_{\text{real-time}} = \frac{\sum_{m=1}^{n} P_{\text{real-time,m,i}}}{n}, \ i = 1,2,\ldots, 96 \).

The average value of the electricity price at each time point at 96 points in the day-ahead and real-time for many historical days is \( \{P_{\text{day-ahead}}, P_{\text{day-ahead,2}}, \ldots, P_{\text{day-ahead,96}}\} \) and \( \{P_{\text{real-time}}, P_{\text{real-time,2}}, \ldots, P_{\text{real-time,96}}\} \), the mid-to-long term 96 points electricity price is \( \{P_{\text{mid-long}}, P_{\text{mid-long,2}}, \ldots, P_{\text{mid-long,96}}\} \), where \( P_{\text{mid-long,1}} = P_{\text{mid-long,2}} = \ldots = P_{\text{mid-long,96}} \), the 96 points electricity price between the day-ahead and mid-to-long term is \( P_{\text{ahead-long}} = P_{\text{day-ahead}} - P_{\text{mid-long}} \), and the 96 points electricity price difference between the real-time and day-ahead is \( P_{\text{real-ahead}} = P_{\text{real-time}} - P_{\text{day-ahead}} \), the historical multi-day day-ahead ,mid-to-long term 96 points electricity price difference at each time points is \( \{P_{\text{ahead-long}}, P_{\text{ahead-long,2}}, \ldots, P_{\text{ahead-long,96}}\} \), among them the maximum value of the 96 points spread between the day-ahead and mid-to-long term is \( P_{\text{ahead-long,max}} \) and the minimum value is \( P_{\text{ahead-long,min}} \) ,historical multi-day real-time electricity price spread at each time point at 96 points day-ahead is \( \{P_{\text{real-ahead}}, P_{\text{real-ahead,2}}, \ldots, P_{\text{real-ahead,96}}\} \), among them the maximum value of the 96 points spread in real-time and day-ahead is \( P_{\text{real-ahead,max}} \) , and the minimum value is \( P_{\text{real-ahead,min}} \).

4.2. Electric quantity data preparation

Using the method of similar day selection above, historical data records of n similar days were selected to obtain the actual electric quantity information of the spot transaction history of the agent user per day, namely 15min/point, 96 points per day. N groups of historical actual 96 point electric quantity information is \( \{Q_{\text{actual,1}}, Q_{\text{actual,1,2}}, \ldots, Q_{\text{actual,1,96}}\}, \ldots, \{Q_{\text{actual,n}}, Q_{\text{actual,n,2}}, \ldots, Q_{\text{actual,n,96}}\} \). Then the actual electric quantity at 96 points is \( Q_{\text{actual}} = \frac{\sum_{m=1}^{n} Q_{\text{actual,m,i}}}{n}, \ i = 1,2,\ldots, 96 \). The average quantity of
electricity at each time point of 96 points in multiple historical days is \[ \{Q_{\text{actual}1}, Q_{\text{actual}2}, \ldots, Q_{\text{actual}96}\} \], and the total quantity of electricity at each time point of 96 points in multiple historical days is \[ \sum_{i=1}^{96} Q_{\text{actual}i} \].

### 4.3. Mid-to-long term electricity purchasing curve generation

Because a few days ago, mid-to-long term 96 points gap and real-time, has 96 points gap exists difference between maximum and minimum values, and the user side mid-to-long term contract power per hour and the user side real-time market time-sharing power. There is a deviation on the floor, consider using a linear equation \[ y = ax + b \], combined with the user side per hour power for mid-to-long term futures contracts allow the deviation on the proportion of lower limit and the user side time-sharing power allows real-time market calculation deviation ratio of upper and lower limits of a and b values, calculation, mid-to-long term, electricity rate coefficient can be considered in the practical application of appropriate to zoom in on deviation ratio to calculate.

The upper and lower limits of the allowable curve deviation of mid-to-long term are \( P_{\text{aheadLong max}} \) and \( P_{\text{aheadLong min}} \), and where the deviation is 0, the coefficient of mid-to-long term declaration is 1, then \( b = 1 \). Considering the value of the price difference between the two exists positive and negative, where the maximum value of the price is \( P_{\text{aheadLong max}} \), and the minimum value is \( P_{\text{aheadLong min}} \).

When \( P_{\text{aheadLong max}} > P_{\text{aheadLong min}} > 0 \), there

\[
 a_{\text{midlongCurveUpperLimit}} = a_{\text{midlongCurveLowerLimit}} = \frac{\lambda_{\text{midlongCurveUpperLimit}} - 1}{P_{\text{aheadLong max}}} \tag{1}
\]

When \( P_{\text{aheadLong max}} > 0 \) and \( P_{\text{aheadLong min}} < 0 \), there

\[
 a_{\text{midlongCurveUpperLimit}} = \frac{\lambda_{\text{midlongCurveUpperLimit}} - 1}{P_{\text{aheadLong max}}} \tag{2}
\]

\[
 a_{\text{midlongCurveLowerLimit}} = \frac{\lambda_{\text{midlongCurveLowerLimit}} - 1}{P_{\text{aheadLong min}}} \tag{3}
\]

When \( P_{\text{aheadLong min}} < P_{\text{aheadLong max}} < 0 \), there

\[
 a_{\text{midlongCurveUpperLimit}} = a_{\text{midlongCurveLowerLimit}} = \frac{\lambda_{\text{midlongCurveLowerLimit}} - 1}{P_{\text{aheadLong min}}} \tag{4}
\]

Where \( x, y \) can be appropriately modified, judging the spread of 96 points day-ahead and mid-to-long term \( \{P_{\text{aheadLong}1}, P_{\text{aheadLong}2}, \ldots, P_{\text{aheadLong}96}\} \), the relationship between the maximum \( P_{\text{aheadLong max}} \)
and the minimum \( P_{\text{aheadLongmin}} \) and the size of the 0, using linear equation \( y = ax + b \) to calculate coefficient of medium and long-term electricity 96 points \( \{K_1, K_2, ..., K_{96}\} \), combined with mid-to-long term deficiency mid-to-long term recycling fees specified in the contract amount not less than, 95% of the total electricity consumption conditions and the actual user history for 96 points each point averages \( \{Q_{\text{actuali}}, Q_{\text{actual2}}, ..., Q_{\text{actual96}}\} \), a power calculation for mid-to-long term, 96 basis points of electricity value \( \{Q_{\text{midLongBasei}}, Q_{\text{midLongBase2}}, ..., Q_{\text{midLongBase96}}\} \) where \( Q_{\text{midLongBasei}} = 0.95 \times K_i \times Q_{\text{actuali}} \). The sum of the basic value of daily power declaration at 96 points in the program is \( \sum_{i=1}^{96} Q_{\text{midLongBasei}} \). By comparing the sum of the actual power at each time point of 96 points in multiple historical days \( \sum_{i=1}^{96} Q_{\text{actuali}} \) with the sum of the basic value of the power declaration at 96 points in mid-to-long term days \( \sum_{i=1}^{96} Q_{\text{midLongBasei}} \), the optimization multiplier coefficient of the power declaration at 96 points in mid-to-long term days is \( k_1 = \frac{\sum_{i=1}^{96} Q_{\text{actuali}}}{\sum_{i=1}^{96} Q_{\text{midLongBasei}}} \). The optimization ratio coefficient of mid-to-long term daily 96 points electric quantity declaration is multiplied by the basic value of mid-to-long term daily 96 points electric quantity declaration, and the optimization value of mid-to-long term daily 96 points electric quantity declaration is calculated \( \{Q_{\text{midLongOpti}}, Q_{\text{midLongOpt2}}, ..., Q_{\text{midLongOpt96}}\} \) where \( Q_{\text{midLongOpti}} = k_1 \times Q_{\text{midLongBasei}} \).

### 4.4. Day-ahead purchase curves generation

Similar to the generation principle of mid-to-long term electricity purchase curve, the upper and lower limits of the allowable ratio of time-of-use electric quantity deviation in the real-time market on the user side are \( \lambda_{\text{upperLimitExcess}} \) and \( \lambda_{\text{lowerLimitExcess}} \), and when the deviation is 0, the coefficient of day-ahead declaration is 1, then \( b = 1 \). Considering the maximum value of real-time and day-ahead 96 points price difference, the minimum value has positive and negative values.

When \( P_{\text{realAheadmax}} > P_{\text{realAheadmin}} > 0 \), there

\[
a_{\text{upperLimitExcess}} = a_{\text{lowerLimitExcess}} = \frac{\lambda_{\text{upperLimitExcess}} - 1}{P_{\text{realAheadmax}}} \tag{5}
\]

When \( P_{\text{realAheadmax}} > 0 \) \& \( P_{\text{realAheadmin}} < 0 \), there

\[
a_{\text{upperLimitExcess}} = \frac{\lambda_{\text{upperLimitExcess}} - 1}{P_{\text{realAheadmax}}} \tag{6}
\]

\[
a_{\text{lowerLimitExcess}} = \frac{\lambda_{\text{lowerLimitExcess}} - 1}{P_{\text{realAheadmin}}} \tag{7}
\]

When \( P_{\text{realAheadmin}} < P_{\text{realAheadmax}} < 0 \), there
Determine the relationship between the real-time and day-ahead 96 points price difference \( \{P_{\text{realAhead}1}, P_{\text{realAhead}2}, \ldots, P_{\text{realAhead}96}\} \), the maximum values \( P_{\text{realmAhead\,max}} \) and the minimum values \( P_{\text{realmAhead\,min}} \) and 0 at each time point, use the linear equation \( y = ax + b \) to calculate the 96 points electricity declaration coefficient \( \{L_1, L_2, \ldots, L_{96}\} \), and combine the user’s historical multi-day actual 96 points electricity average value \( \{Q_{\text{actual}1}, Q_{\text{actual}2}, \ldots, Q_{\text{actual}96}\} \) at each time point in multiple days of history. The basic value of electricity declaration at day-ahead 96 points is \( \{Q_{\text{day\,Ahead\,Base1}}, Q_{\text{day\,Ahead\,Base2}}, \ldots, Q_{\text{day\,Ahead\,Base96}}\} \). Where \( Q_{\text{day\,Ahead\,Basei}} = L_i \times Q_{\text{actuali}} \). Then, the sum of the basic value of the electricity declaration at the day-ahead 96 points is \( \sum_{i=1}^{96} Q_{\text{day\,Ahead\,Basei}} \).

By comparing the sum of the actual 96 points electric quantity \( \sum_{i=1}^{96} Q_{\text{actuali}} \) at each time point in the past many days with the sum of the basic value of the 96 points electric quantity \( \sum_{i=1}^{96} Q_{\text{day\,Ahead\,Basei}} \) declared earlier, the optimization multiplier coefficient of the 96 points electric quantity declared earlier is \( k2 = \frac{\sum_{i=1}^{96} Q_{\text{actuali}}}{\sum_{i=1}^{96} Q_{\text{day\,Ahead\,Basei}}} \).

The optimization ratio coefficient of the 96 points electric quantity declaration day-ahead is multiplied by the basic value of the 96 points electric quantity declaration day-ahead, and the optimization value of the 96 points electric quantity declaration day-ahead is calculated \( \{Q_{\text{day\,Ahead\,Opt1}}, Q_{\text{day\,Ahead\,Opt2}}, \ldots, Q_{\text{day\,Ahead\,Opt96}}\} \) where \( Q_{\text{day\,Ahead\,Opti}} = k2 \times Q_{\text{day\,Ahead\,Basei}} \).

Therefore, the optimized value of the 96 points daily electricity in mid-to-long term is \( \{Q_{\text{mid\,Long\,Opt1}}, Q_{\text{mid\,Long\,Opt2}}, \ldots, Q_{\text{mid\,Long\,Opt96}}\} \), the optimized value of the electricity declared at 96 points day-ahead is \( \{Q_{\text{day\,Ahead\,Opt1}}, Q_{\text{day\,Ahead\,Opt2}}, \ldots, Q_{\text{day\,Ahead\,Opt96}}\} \).

5. Conditional Constraint

Pilot provinces of Shanxi, according to the domestic spot settlement data during commissioning in November 2020 and the latest trading rules, and user side mid-to-long term contract total amount not less than 95% of the total power consumption, long curve deviation allowed proportion on floor 2, and 0.5, respectively, a user side real-time market time-sharing power deviation allows lower limit on ratio was 1.5 and 0.5, respectively, some sell electricity company in Shanxi Province and analyzed the proxy user history of electricity supply. The combined with historical data is expected to sell electricity company on November 20, 2020 the proxy user actual total power consumption for 4 940.872 MWh, which plans to declare the mid-to-long term contract power to the total value of the day for 4 694.828 4 MWh, have power to declare the total value of 4 940.872 MWh, using the proposed considering similar day constraint conditions and sell electricity company spot trading strategies for mid-to-long term 96 points and day-ahead 96 points purchasing electricity curve decomposition and buy electric curve of the declaration, the mid-to-long term, day-ahead and real-
time electricity price curve as shown in figure 2. The electric quantity curve reported by the electricity selling company using the original strategy is shown in Figure 3, and the electric quantity curve reported by the electricity selling company using the auxiliary trading strategy is shown in Figure 4.

**Figure. 1** Mid-to-long-term, day-ahead and real-time electricity price curve

[Graph showing electricity price curves]

**Figure. 2** Electric quantity curve declared by the original strategy

[Graph showing electric quantity curves]

**Figure. 3** Electric quantity curve declared by auxiliary trading strategy

[Graph showing electric quantity curves]

According to the application situation of the 96 points daily electricity purchasing curve in the mid-to-long term and the 96 points optimization curve declaration day-ahead, combined with the spot market price information, the original strategy and auxiliary trading strategy were selected to carry out a comparison of the trading results in the spot market on November 20. The trading results are shown in Table 1.
Through comparison, it can be found that the auxiliary trading strategy can enable the electricity selling company to obtain better earnings on November 20. In order to test the effectiveness of the auxiliary trading strategy, the trading results of the original strategy and the auxiliary trading strategy of the electricity selling company on November 21, solstice and November 25 are compared as follows. The trading results are shown in table 2.

| Date   | Compare                      | Original strategy | Auxiliary trading strategy |
|--------|------------------------------|-------------------|---------------------------|
| 11-21  | Revenue / (RMB)              | 328 923.37        | 374 026.33                |
|        | Kilowatt yield earnings      | 64.48             | 73.3                      |
|        | / (RMB/MWh)                  |                   |                           |
| 11-22  | Revenue / (RMB)              | 25 3482.01        | 389 328.34                |
|        | Kilowatt yield earnings      | 49.69             | 76.3                      |
|        | / (RMB/MWh)                  |                   |                           |
| 11-23  | Revenue / (RMB)              | 382 016.23        | 476 757.24                |
|        | Kilowatt yield earnings      | 74.89             | 93.46                     |
|        | / (RMB/MWh)                  |                   |                           |
| 11-24  | Revenue / (RMB)              | 325 812.52        | 469 474.26                |
|        | Kilowatt yield earnings      | 63.87             | 92.04                     |
|        | / (RMB/MWh)                  |                   |                           |
| 11-25  | Revenue / (RMB)              | 239 259.27        | 407 005.35                |
|        | Kilowatt yield earnings      | 46.90             | 79.79                     |
|        | / (RMB/MWh)                  |                   |                           |

What needs to be explained in particular is that in the above table, the settlement of electricity charges, cost of electricity per kilowatt hour, income of electricity per kilowatt hour and so on have not yet included the adjustment of electricity charges, refund and payment of electricity charges, blocking costs, government funds, line loss discount and transmission and distribution electricity charges, etc., which shall be subject to the settlement sheet issued by the trading center.

### 6. Conditional

This article proposes a spot trading strategy for electricity retail companies that considers multiple constraints. First, the similar day method is selected, and the mid-to-long term, day-ahead, and real-
time historical electricity prices are statistically analyzed and calculated on the basis of similar days, combined with the "user-side excess Constraints such as “profit recovery fee”, “mid-to-long term deficit recovery fee” and “mid-to-long term curve deviation recovery fee” are used to optimize the mid-to-long term, 96 points day-ahead power declaration curve in spot transactions. Practical application shows that the auxiliary trading strategy of this article is reasonable and feasible, can obtain relatively stable income for the retail company, reduce the transaction risk, and has important practical significance. However, this article only conducts statistical analysis on historical power data in terms of date types and temperature differences, and does not consider other related information such as weather, user power demand, the impact of major social events, demand side response, and orderly power use. Which makes the auxiliary trading strategy have certain limitations, and the income of electricity sales companies cannot be further improved. Further in-depth research is needed in the follow-up.

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