Research on Competitiveness of Incremental Distribution Market Based on Reliability Electricity Charge

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Abstract. With the maturity of the medium- and long-term trading market, the gradual start-up of the spot market and the full liberalization of the operating rights of the incremental distribution network, the power advantage capital has launched the trial of the incremental distribution network pilot, and how to carry out the market of the incremental distribution network. Chemical operations have become the focus of research in the market. Based on this, for the park-type incremental power distribution project, the basic module group that constitutes the typical power supply mode is analyzed and determined, and the influence of the key basic modules on the power supply reliability rate is studied, and the typical power supply mode of the park with different reliability levels is obtained. This paper studies the bidding strategy of power producers in the electricity market, introduces the game theory of electricity market, establishes a two-level bidding strategy model based on probability theory under incomplete information, and proposes a solution algorithm and framework for the mathematical model. The genetic algorithm is used to find the optimal quotation parameters.

1. Introduction
As a key link in the reform of the power system, the expansion of the incremental power distribution business will help encourage and attract social capital to participate in the investment network construction, and will play a positive role in improving the development speed of the distribution network. At the same time, the existing distribution and sales market pattern and even the terminal energy production and consumption pattern may undergo profound changes. The business of power grid enterprises in the planning, construction, service and operation of distribution network will inevitably be affected, from the corporate strategy. Starting from development and business decision-making, it is necessary to conduct an in-depth analysis of the impact of reform policies, and then to propose scientific and reasonable coping strategies.

2. Electricity market incremental power distribution theory
After the spot market is officially launched, the regional electricity market will be formed at the provincial level. The two major power trading centers are responsible for implementing the national West-East power transmission strategy, implementing national mandatory plans and local inter-governmental framework agreements, providing services for cross-regional and inter-provincial market
transactions, and promoting inter-provincial adjustments and clean energy consumption. The provincial-level power trading institution is linked with the dispatching agency. On one hand, it is responsible for bilateral transactions and centralized bidding transactions in the medium and long-term market. On the other hand, it is responsible for real-time electricity balance and trading in the spot market, including the day-to-day market and the intra-day real-time market. The specific process is as follows.

(1) The market trading entity submits the daily power consumption curve, the regional node position and the current electricity adjustment information agreed by the medium and long-term contract before the agreed time limit. The power dispatching agency issues the load forecasting curve for the power generation enterprise based on the above information, including the unit. Remaining capacity, unit operating capacity, unit quotation curve, etc.

(2) According to the reporting information of the power generation enterprise and the load forecasting amount, the power trading institution takes various security constraints such as network topology blocking, system stability margin and accident checking capability as constraints, and aims at maximizing social welfare. The unit combination and the regional/node marginal base price $P_1$ of the power generation enterprise at each time [1].

(3) As the operation and maintenance trader of the transmission and distribution network, the grid company charges the fixed transmission and distribution price $P_2$ within the transaction. For users in the incremental distribution network that are not part of the grid investment operation, $P_2$ reduces the distribution network operation compared with other users. Part of the cost.

(4) The incremental distribution network operator of the power user collects the additional income of the distribution network, including the basic distribution network operation and maintenance fee $P_3$ and the optional value-added service fee $P_4$, so the real-time power of the user in the incremental distribution network the electricity fee is $P = P_1 + P_2 + P_3 + P_4$.

(5) Users can purchase electricity once in the market in the day and in the real-time market in the day. Considering the balance stability of the system, the amount of electricity purchased by the user side will be borne by the user. The power shortage is supplied by the regional power operator and is in $P_1$. An additional premium power service fee will be charged on the basis.
3. Analysis of power supply reliability rate

3.1. Reliability level analysis of grid structure modules

The 110-35kV power grid structure is relatively simple. For parks with high requirements on power supply reliability, a chain structure should be adopted, and the substation should be connected by π connection. This section focuses on the reliability of the 10kV grid structure.

a) Single radiating wiring. This wiring method cannot transfer the load in the event of a fault, and generally narrows the fault range by means of line segmentation. The average power outage time of a single radiating line is expressed as:

$$ t' = gFR + rFR \frac{k + 2}{2(k + I)} $$

Where: $k$ is the number of line segmentation switches, one; $g$ is the time required for fault isolation, h; $r$ is the time required for fault repair, h; $F$ is the annual failure rate of the feeder, sub/km; $R$ is the length of the line, km. With the increase of the number of line segments, the reliability of the power supply of the line is improved, but the lifting effect is less and less significant. Generally, it is more reasonable to take the three segments of the line [2].

b) Hand-in-hand wiring. The wiring method refers to the single contact wiring mode of the overhead line or the single ring network connection mode of the cable line. When the line or load switch fails, the power can be restored from the other line to the fault line through the tie switch. The average power outage time of the line hand-wired is expressed as:

$$ t'' = gFR + rFR \frac{I}{k + I} $$

Where: $I$ is the number of tie lines.

c) Overhead multi-segment moderate contact wiring. There are a large number of tie lines in this connection mode. When a fault occurs, each line can restore power through its own contact line. In the area with high load density, the connection mode has higher power supply reliability than the hand-held connection mode.
d) Cable double loop network. Manually operated communication switches are installed between the ring network rooms of the double-loop network of the access cable or the two busbars of the power distribution room, so that the double-loop network can meet the "N-2" power supply standard and has higher power supply reliability than the single-ring network [3].

e) The cable is “more than one ready”. The "multiple supply and one backup" grid structure overcomes the problem that the relay power supply is limited by the transmission capacity of the ring network, and further improves the reliability of the power supply. However, since there is only one backup power supply, when the network has multiple failures, there may be cases where the backup line cannot be transferred to all loads. Therefore, the actual general control is 2 to 3 power supply lines, not too much.

3.2. Reliability level analysis of distribution automation module

Distribution automation technology can significantly reduce the power outage range and power outage time due to fault factors. Different reliability targets can be achieved by properly configuring the type and number of distribution automation terminals installed on each feeder. The grid structure of the park is considered in accordance with the "N-1" power supply requirements. Assume that the line segmentation switch and the tie switch are all configured according to the “three remote” terminal, and $t_1$ is the time required for fault repair; in order to meet the reliability requirement $F_{set}$ of the power failure caused only by the fault factor, the number of segment switches $k_3$ should be satisfied.

$$k_3 \geq \frac{t_1F}{8760(1-F_{set})} - 1 \geq 0$$

(3)

Assume that the line segmentation switch and the tie switch are all configured according to the “two remotes” terminal. In order to meet the reliability requirement of the power failure caused by only the fault factor, $F_{set}$, the number of segment switches $k_2$ should be satisfied.

$$k_2 \geq \frac{t_1F}{8760(1-F_{set})-t_2F} - 1 \geq 1$$

(4)

Where $t_2$ is the time required to isolate the fault zone.

4. Power plant bidding online

4.1. The bidding strategy of the power producer

Power companies can determine their own bidding strategies based on their production costs. By changing the cost curve of the quotation, the load distribution and node price of the system can be changed, which affects the benefit of all power producers [4]. It may also cause other participants to change their bidding strategies, which in turn can redistribute the benefits of the entire system. In this chapter, analyze three typical bid strategies for discrete types:

High price strategy H – quoted at 20% above cost, the generator cost function in the model correspondingly becomes:

$$C_{IH} = 1.2\left(\frac{1}{2}a_ip_{gi}^2 + b_ip_{gi} + c_i\right)$$

(5)
The medium price strategy M – quoted at actual cost, the generator cost function in the model correspondingly becomes:

$$C_{iM} = 1.0 \left( \frac{1}{2} a_i p_{gi}^2 + b_i p_{gi} + c_i \right)$$ (6)

Low price strategy L – quoted at 20% below cost, the generator cost function in the model correspondingly becomes:

$$C_{iL} = 0.8 \left( \frac{1}{2} a_i p_{gi}^2 + b_i p_{gi} + c_i \right)$$ (7)

The power producers can choose the above three quotation strategies, or the high price strategy to raise the market price, or the low-price strategy to sell more electricity, or the medium price strategy and the pool cooperation, the purpose of which is to maximize the benefits. Of course, the final strategy choice depends on the outcome of the game of all power producers [5].

### 4.2. Optimal distribution of active load

In the game model, the players are the power producers. Their decision-making steps in the game model consist of the following two steps: calculating the income, forming the payment table, and playing the game.

After solving the optimal distribution plan of the load, according to the principle of unified clearing price, find the value of the highest electricity price of all generator nodes as the market clearing price $\rho = \max \{\rho_1, \cdots, \rho_{ng}\}$. By calculating the following income function, the income of the power producer can be obtained:

$$u_i = \rho p_i - f_i = \rho p_i - \left( \frac{1}{2} a_i p_{gi}^2 + b_i p_{gi} + c_i \right)$$ (8)

By analogy, the payment of each power producer can be obtained from all $3n$ strategic combinations, so that a payment schedule can be formed.

### 4.3. High reliability electricity bill implementation plan

Based on the high reliability/basic power supply mode and calculation model of the campus, the campus reliability electricity cost implementation plan includes the following steps. Step 1: To meet the high reliability requirements of the park, determine the high-reliability power supply mode of the campus based on the typical power supply basic module group; Step 2: Calculate the full life cycle cost of the campus using the high-reliability power supply mode; Step 3: Calculate the life cycle cost of the basic power supply mode for the park [6]; Step 4: Calculate the reliability competition cost according to the calculation model; Step 5: Combine the reliability competition cost according to the service life agreed by the grid enterprise and the park and the current loan interest rate Calculate the monthly reliability costs allocated to the service years.

### 5. Experimental verification

Taking a high-tech zone as an example, the high-reliability power supply scheme and the basic mode power supply scheme of the high-tech zone are given, and the corresponding high-reliability electricity charges are calculated.
5.1. Reliability-based electricity tariff incremental power supply scheme
According to the high reliability power supply target of the park, the basic modules that constitute the high-reliability power supply scheme of the park are as follows: 110kV adopts chain structure, 10kV adopts cable double loop network structure; distribution automation adopts centralized fault processing mode, all “three remote” The electric terminal is configured, and the communication method is optical fiber. The details of the high reliability program plan are as follows.

a) High-voltage grid planning. In the year of saturation, the 110kV grid in the high-tech zone will form a three-chain grid structure with 220kV A Station, B Station, C Station and D Station as power points. Open loop operation in the normal mode, with the ability to transfer load in the event of an accident, the power supply reliability can meet the power demand of the high-tech zone.

b) Medium voltage grid planning. According to the double-ring network structure of the cable power supply area, the medium-voltage grid frame consists of 40 sets of double-ring network wiring from different substations or different bus lines of the same substation, and a total of 160 times of 10kV cable lines are planned. Each line is arranged in three ring network cabinets, two of which are ring network cabinets and one is a ring network cabinet. A total of 480 ring network cabinets are required. The line load rate is controlled by 50% [7]. The grid structure satisfies the "N-2" safety criterion and has higher power supply reliability than the single ring network. Since each line has a three-segment structure, the fault range is greatly reduced. According to the centralized fault handling mode, the distribution automation is all configured according to “three remotes”, and the fault processing time is greatly shortened.

5.2. Reliability electricity price
Estimate the life cycle cost of the high-reliability power supply scheme and basic power supply scheme of 110kV and below (including distribution automation) in the high-tech zone, see Table 1.
Table 1. Full life cycle cost of each power supply scheme

| cost          | Construction Content | High reliability solution | Basic power supply plan |
|--------------|----------------------|----------------------------|-------------------------|
|              | Construction scale   | Cost / 10,000 yuan         | Construction scale      | Cost / 10,000 yuan   |
| construction | 110kV substation     | 600MVA                     | 45500                   | 600MVA               | 45500                   |
|              | 110kV line           | 75.06km                    | 8256.6                  | 47.77km              | 5254.2                  |
|              | 10kV line            | 233.46km                   | 7509.5                  | 233.46km             | 17509.5                 |
|              | Ring network cabinet | 480 seats                  | 16320                   | 160 seats            | 2880                    |
|              | total                | 87586.1                    | 71143.7                 |                        |                         |
| annual       | 110kV substation     | 335.48                     | 335.48                  |                        |                         |
| maintenance  | 110kV line           | 41.49                      | 26.4                    |                        |                         |
|              | 10kV line            | 94.34                      | 94.34                   |                        |                         |
|              | total                | 471.31                     | 456.22                  |                        |                         |
| scrap        | 110kV and below      | 3941.37                    | 3201.47                 |                        |                         |

It is calculated that the reliability competition cost of the grid enterprises invested in the high-reliability planning scheme of the high-tech zone is 170,282,300 yuan, and the reliability price of the park to be paid monthly is 1,138,100 yuan. The cost of reliability competition accounts for 17.28% of the cost of high-reliability power supply solutions, which is mainly reflected in the construction of the communication channel of the high-voltage distribution network and the construction of the ring network cabinet and the distribution automation of the medium-voltage distribution network.

6. Conclusion
In summary, through the discussion of these different contents, it can provide effective protection for the improvement of the operation status of the incremental distribution network and the enhancement of the effect, meet the development requirements in the background of the power spot market, and make the distribution network in practice. Have a good profit situation. Therefore, in the process of promoting the development of distribution network and reducing its operational risk in the future, we should pay attention to the incremental operation situation and implement the corresponding analysis through the analysis of the situation change under the power spot market and the consideration of the functional characteristics of the distribution network. Work plan to achieve timely treatment of factors affecting the operation of the distribution network. In the long run, it can enrich the practical experience and research content of efficient operation of distribution network.

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