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# Wind Power Grid Trading System Based on Risk Management and Control

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***Abstract:***

In order to realize the purpose of power market risk management under the goal of double carbon management, this paper analyzes the basic theory of wind direction management, establishes the risk mathematical model of the whole life cycle of wind power investment, and puts forward the corresponding countermeasures. This paper formulates the rules of power market, combined with the risk of wind power participating in market transactions, proposes a new method, which carries out risk assessment of wind power participating in market transactions based on utility function. The example results show that the new method is effective, and the utility function can provide a better risk management and control scheme for wind power generators than the expected value and mean square error.

***Keywords****: Wind power investment, Electricity trading, Risk management, Time-of-use electricity price, Electricity purchase and sales strategy.*

## I. INTRODUCTION

Although power selling companies are in the power industry, their essence is still to make profits. Under the condition that the power trading center continues to assess the deviation of power consumption of trading members, the operation risk of power selling companies is further amplified. At present, the power purchase and sales mode of each power sales company is relatively single, which can not well meet the new requirements put forward by the power reform, and it is difficult to effectively deal with the power assessment of the trading center[1]. How to innovate the way of power purchase and sales to attract and retain more users, and how to win more profits for power sales companies through reasonable risk assessment and management are the urgent problems to be solved by power sales companies.

As a middleman in power market transactions, wind power generation and power sales companies connect power generation market, transmission and distribution market and power consumption market, and take power purchase and sales transactions as their main market operation business. However, the power purchase and sale trading activities in the wind power market are facing many uncertainties and

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risks[2]. How to innovate the power purchase and sale mode, avoid market risks and obtain good economic benefits and social credit is an urgent problem for power sales companies.

This paper studies the wind power grid Trading System based on risk management and control. By analyzing the relevant theories and data of power purchase and sales business of power sales companies, and analyzing the power consumption behavior of users according to the load curve of power users, a customized electricity price design model of power sellers considering the characteristics of users' power consumption is proposed. A wind power grid Trading System Based on risk management and control is proposed to adapt to the environment of China's power market.

## II. MARKET MODEL AND RISK ANALYSIS

### 2.1 Market Model

The reform of the power market and the opening of the power selling side market will inevitably bring about the diversification of market subjects and the transformation of functions. From the vertical integration of power generation, transmission, distribution and sales to the complete retail competitive market model, the market environment under different degrees of openness has remarkable characteristics. The existing electricity spot market model prototype is the spot market model of PJM in the United States. At present, the market is generally retail competition mode[3]. Because most countries and regions start with large power users and expand the scope of opening up step by step, which is more conducive to the smooth and stable progress of market reform. When the power market is fully opened, all power users have with the option, you can freely purchase electricity from power plants or power selling companies, which indicates that the market has entered the retail competition mode.

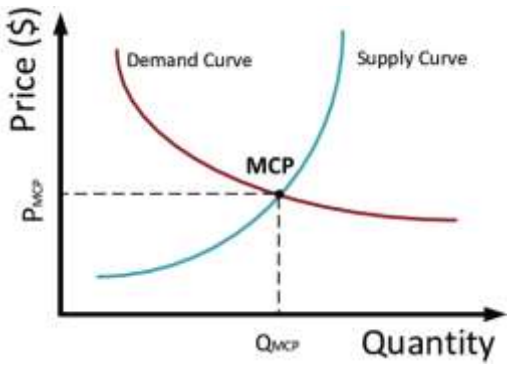


Fig 1: Schematic diagram of market clearing

Under this mode, the power grid company no longer has any monopoly power, and the competition between supply and demand is more intense. The retail competition model is generally regarded as a very advanced model, but the complexity of its implementation makes it unsuitable for countries and regions

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without corresponding supporting measures, infrastructure and development experience, because it will significantly increase the transaction cost of the market. At present, the countries that have adopted this mode mainly include Britain and Australia, and Japan is also developing from wholesale competition mode to retail competition mode.

The Schematic diagram of market clearing is shown in Fig 1.The most commonly used market clearing mechanism is a simple summary method, that is, the independent system operating mechanism selects the lowest quoted power generation first, and then selects the power generation at the next lowest price until the power generation can meet the total power demand, so as to form a power generation curve. When demand quotation is allowed, the demand curve will be formed by a similar combination process of quotation from high to low[4]. The market clearing price within the system is usually the quotation of the last generator planned to generate electricity in this period, as shown in Fig 1. After the market clearing price is determined, the independent system operation organization shall review the plan and check the power flow to ensure system stability and power supply safety. In some cases, the plan can be modified to provide rotating standby or alleviate network congestion.

2.2 Risk Analysis

Market risk refers to the risk of changes in the price or value of derivatives caused by adverse changes or sharp fluctuations in the market price of the underlying assets. Among them, the market price of basic assets includes the changes of market interest rate, exchange rate, bonds, stocks and so on. The risk of power market is a general term for all kinds of potential or existing risks in power market. The risks generated by power selling companies form financial derivatives with power attributes through packaging, contracting, futures and option trading, and form medium and long-term stable transactions by increasing capital injection and risk hedging, which can reduce the risks caused by market fluctuations. The introduction of multi-party capital can correctly guide the direction of power investment and alleviate the contradiction between supply and demand in areas with tight power supply[5]. When the power selling company conducts high-risk transactions, it can also use the insurance mechanism to reduce the risk caused by decision-making and stabilize the return on investment.

On the basis of risk assessment, power sales companies can formulate reasonable power purchase and sales strategies through certain risk management measures. Compared with the financial field, power selling companies need to take into account the balance of energy flow and cash flow in the power purchase and sale market, and ensure the safe and stable operation of the system in their distribution network in real-time delivery.

In different power market environments, power selling companies can dynamically adjust power selling strategies, correctly guide consumers to use electricity reasonably, and try to obtain the load curve matching the power purchase curve. While obtaining profits, they can also reduce the deviation power assessment caused by excessive deviation of load curve.

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## III. WIND POWER GRID ACCESS TRADING SYSTEM

### 3.1 Mathematical Model

Let $X$ be the power purchase combination scheme vector of the power selling company, the dimension is n, R represents the quotation scheme of the power supplier in the power purchase market, and $X$ is defined in the range of $R$, i.e. $X \in RN$. $Y$ represents the yield vector generated by the power selling company after adopting a certain power purchase strategy, with dimension $M$. its essence is the impact of random factors of the market on the loss. Using the form of yield is conducive to comparing the risk generated by different power purchase strategies under the same benchmark conditions. $Y$ is defined as $Y \in RN$.

Let $f\ (x, \mathrm{y})$ be the loss function of a certain power purchase strategy used by the power selling company, and equation (1) is expressed as the power purchase strategy vector of the power selling company.

$$x^{\mathrm{T}} = \left(x_1, x_2, x_3, \square, x_q\right)$$
$$\sum_{i}^{q} x_i = 1 \tag{1}$$

Where: $Xi$ represents the proportion of electricity purchased by the power selling company in the total electricity purchased by a power supplier; $Q$ represents the number of power suppliers selected by the power selling company for power purchase.

Equation (2) represents the revenue vector of the power selling company under the $X^T$ power purchase strategy under the action of market factors:

$$y^{\mathrm{T}} = \left(y_1, y_2, y_3, \square\square, y_q\right) \tag{2}$$

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The corresponding conversion rate of return is shown in formula (3):

$$y_i = (C - p_i) / C \tag{3}$$

According to the definition of VA, the joint probability density function of $Y$ is set as $P(y)$, so the distribution function of power selling company loss caused by market factor y can be expressed as equation (4):

$$F(x,a) = \int_{f(x,y)} p(y)\mathrm{d}y \tag{4}$$

Where: $a$ represents the critical loss value of the power selling company; Under the joint action of the determined power purchase strategy $X$ and the market factor $Y$, $f(x, a)$ represents the distribution function of the cumulative loss of the power selling company.

3.2 Network Access Transaction Strategy System Flow

Although the risk of the power selling company in power purchase is reflected in the operating difficulties caused by the high power purchase cost and the insufficient return of the final power sales funds, the essence is the power purchase and sale imbalance caused by the rapid change of the market supply and demand environment and the incomplete and insufficient grasp of the market trend and user power consumption information by the power selling company, The sharp rise and fall of price in a short time has a great impact on the cash flow and power flow of power selling companies.

The strategy is considered as follows: in order to overcome the risks caused by the power purchase of the power selling company, it is necessary to conduct a risk assessment on the power purchase strategy of the power selling company. According to the classification of risk assessment methods, CVaR, i.e. conditional value at risk, is selected to conduct a risk assessment on the power purchase strategy of the power selling company, so as to determine a reasonable power purchase strategy of the power selling company[6]. In order to obtain higher profits, investors usually need to face greater risks in the market. Before formulating a reasonable power purchase strategy, power selling companies need to make a correct assessment of their risk tolerance. The final power purchase strategy should be a portfolio that maximizes profits within the range of risks they can bear.

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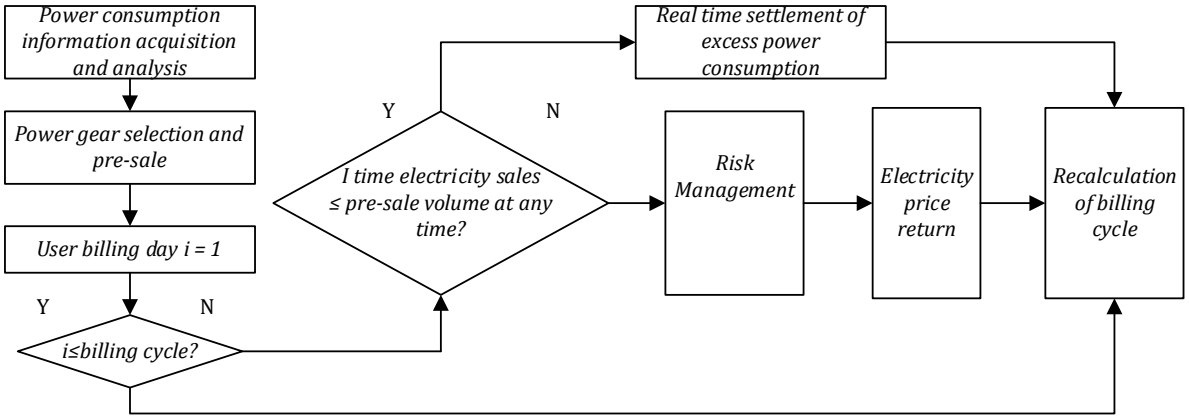


Fig 2: The Network access transaction strategy System flow

The Network access transaction strategy System flow is shown in Fig 2.The process of the power purchase strategy of the power sales company is that the power sales company first signs the power sales agreement with the customer, the power sales company carries out load forecasting after obtaining the user's contract power, evaluates the power suppliers in the power purchase market after obtaining the load forecasting results, selects one or more appropriate power suppliers for power purchase risk assessment, and finally determines the power purchase strategy.

The power trading center has different assessment standards for positive deviation and negative deviation, and the assessment of positive deviation should be relaxed than that of negative deviation. At present, China's power market presents a situation of oversupply, and the power generation environment is relatively loose. The excess power consumption on the demand side can effectively fill the power shortage. Without threatening the security and stability of the power grid, the generation of positive deviation will even make the power supply and consumption show a win-win situation. On the contrary, there are many negative deviations at present, that is, the actual power consumption on the demand side is less than the contract power. The occurrence of negative deviation not only reduces the output of the power plant, but also can change the start-up and shutdown table of the power grid in serious cases. Therefore, the assessment standard of negative deviation in the power trading center is higher than that of positive deviation[7]. When the contradiction between supply and demand in the power market slows down, and even shows a situation that supply is less than demand, the corresponding deviation electricity assessment will also be adjusted to a certain extent.

## IV. EXPERIMENT AND ANALYSIS

### 4.1 Network Access Transaction Strategy

In order to verify the risk assessment of the power selling company under different power purchase strategies, reasonable assumptions will be made on the electricity price of the generator and the maximum

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power purchase cost of the power selling company.

The assumed power supplier 1 in Table I is a power price distribution with low mean and high variance, which means that the sales price is low, but the fluctuation is large. When the power can not meet the power demand, the power selling company needs to purchase additional power from the spot market to supplement. Power supplier 1 is more similar to the wind power generator with higher subsidies. The mean value and variance of power supplier 2 are moderate, which can meet the power demand of power selling companies most of the time, and power supplier 2 is more connected to thermal or hydropower generators. The average value of power supplier 3 is high, but the variance is small, which can basically meet the real-time demand of power sales companies. Power supplier 3 is closer to the rotating reserve in the spot market, which can timely meet the market demand, but the price is high. Assuming that the maximum unit cost of power purchase acceptable to the power selling company is 350 CNY/MWh, the mean and variance of the rate of return of the power selling company are shown in Table II.

**TABLE I. Electricity price distribution data of power suppliers (cny / mwh)**

| **Electricity price index** | supplier 1 | supplier 2 | supplier 3 |
|---|---|---|---|
| Mean value $\upsilon_i$ | 0.4186 | 0.3042 | 0.0715 |
| Variance $\sigma_i$ | 0.6321 | 0.5326 | 0.0867 |

**TABLE II. Revenue distribution data of power selling companies**

| **Yield index** | supplier 1 | supplier 2 | supplier 3 |
|---|---|---|---|
| Mean value $\upsilon_i$ | 0.4317 | 0.3217 | 0.0730 |
| Variance $\sigma_i$ | 0.6628 | 0.5248 | 0.0799 |

100 groups of revenue samples of power selling companies are randomly generated from the normal distribution as the historical data of the simulated power market β Take 0.90 and 0.99respectively, and the lower limit of the expected rate of return of the power sales company is 0.1 and 0.3 respectively. The calculation results of linear programming using software are shown in Table III.

**TABLE III. Power purchase allocation and var and conditional var of power selling companies**

| $\beta$ | $C$ | supplier 1 | supplier 2 | supplier 3 | VaR | CVAR |
|---|---|---|---|---|---|---|
| 0.90 | 0.14 | 0.1354 | 0.1452 | 0.7375 | 0.0198 | 0.0965 |
| | 0.21 | 0.1921 | 0.2498 | 0.5657 | 0.0675 | 0.1766 |
| | 0.26 | 0.3141 | 0.2747 | 0.4174 | 0.1149 | 0.1809 |
| | 0.31 | 0.3810 | 0.3847 | 0.2374 | 0.1473 | 0.123 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | 0.34 | 0.4593 | 0.7416 | 0.0617 | 0.2240 | 0.42 |
| | 0.41 | 0.7509 | 0.2687 | 0.000 | 0.3263 | 0.5017 |
| 0.99 | 0.12 | 0.0951 | 0.1147 | 0.7295 | 0.1528 | 0.1528 |
| | 0.22 | 0.1618 | 0.2178 | 0.5473 | 0.2454 | 0.2754 |
| | 0.26 | 0.2223 | 0.4123 | 0.3478 | 0.2123 | 0.2868 |
| | 0.31 | 0.2874 | 0.5579 | 0.2017 | 0.3333 | 0.3773 |
| | 0.36 | 0.3631 | 0.6177 | 0.0276 | 0.4183 | 0.4273 |
| | 0.41 | 0.7681 | 0.2637 | 0.000 | 0.4757 | 0.7178 |

4.2 Results and Analysis

Confidence and income expectation have a great impact on the power purchase strategy of the power selling company. For a clearer description, the power purchase proportion histogram is shown in Fig 3 and Fig 4.

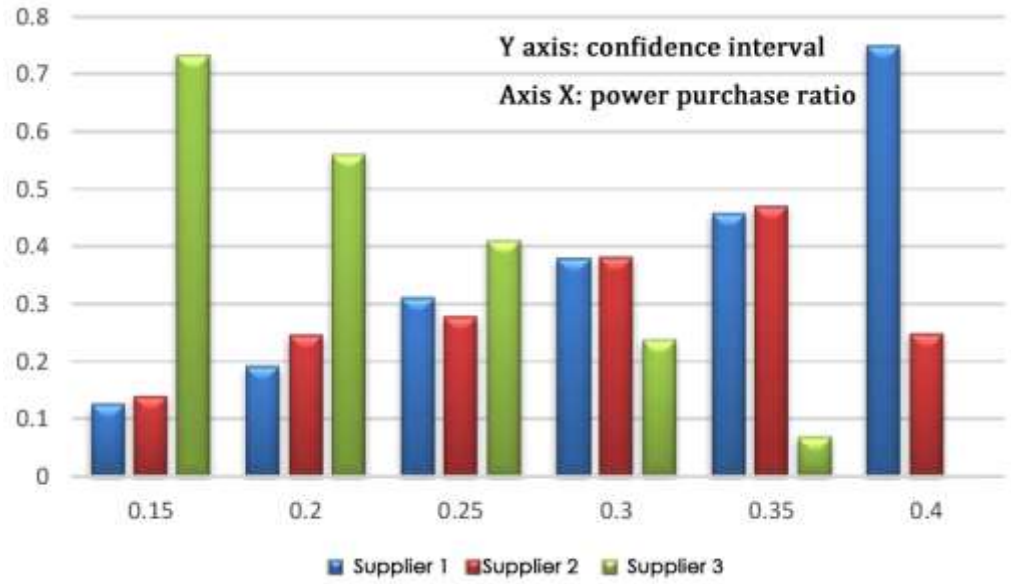


Fig 3: power purchase proportion histogram (Confidence=0.90)

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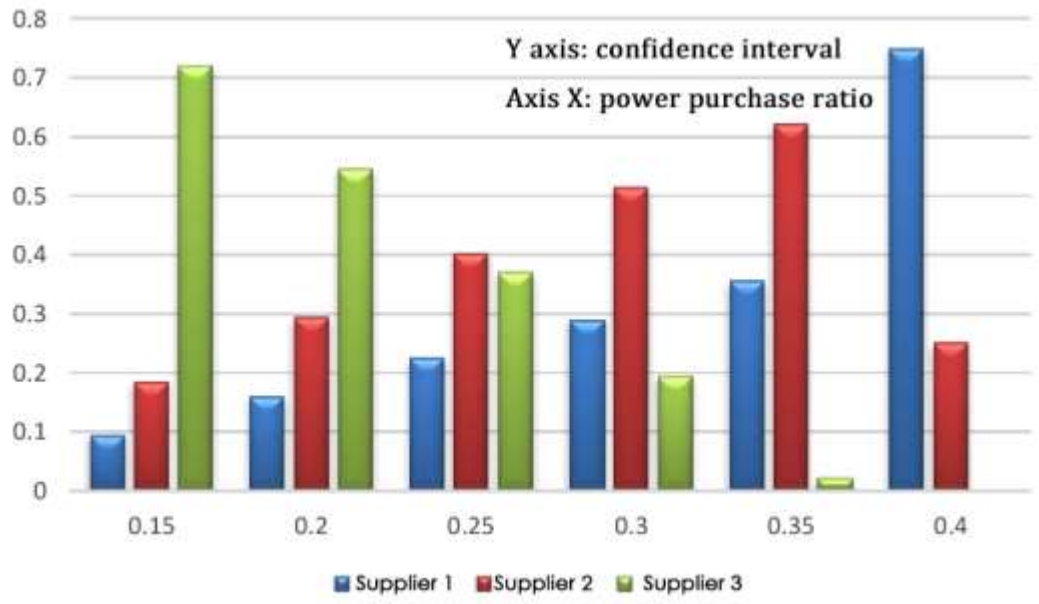


Fig 4: The Network access transaction strategy System flow (Confidence=0.99)

The following conclusions can be drawn from Figs 3 and 4:

(1) According to the definition of effective frontier, it is an effective power purchase combination strategy on the upper side of the effective frontier curve. Considering the same abscissa expected rate of return, the conditional VaR on the effective frontier is the smallest, which is the optimal portfolio under the expected rate of return; In terms of the same ordinate conditional VaR, the expected rate of return on the effective frontier is the largest, which is the optimal portfolio under the conditional var. It can be seen from the Fig that in a certain power purchase market, the power purchase strategy of the power selling company will have the upper and lower limits of the expected rate of return. Under a given assumption, the operation of the minimum expected rate of return and the maximum expected rate of return exceeding the sub range does not converge, that is, under a certain power purchase strategy, the revenue of the power selling company is controllable.

(2) In Fig 4, abnormal changes in the power purchase strategy will occur when the expectation of expected income is too high. The power selling company completely terminates the power purchase from power supplier 3. At the same time, it significantly reduces the power purchased by power supplier 2 against the trend and greatly increases the power purchased from power supplier 1. The power selling company will greatly abandon the reliability of power purchase and excessively pursue high profit margin, which will sharply increase the power purchase risk of the power selling company and have a significant impact on the power selling company. It can be found from the two curves in Fig 3 that when the expected rate of return increases, the conditional risk value also increases, and there will be obvious inflection points in both curves. When the expected rate of return of the power purchase portfolio of the power selling

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company exceeds a certain fixed value, the conditional risk will increase rapidly.

(3) With the increase of the rate of return on power purchase, the power purchased by the power selling company from power supplier 3 gradually decreases, and the power purchased from power supplier 1 and power supplier 2 gradually increases. By longitudinal comparison of different power purchase strategies with 0.90 confidence and 0.99 confidence, it can be found that under the confidence of 0.99, power selling companies prefer to purchase power from power supplier 2, and the growth rate is faster than that from power supplier 1. The mean value of power supplier 2 is greater than that of power supplier 1 and the variance is less than that of power supplier 1, indicating that the power purchase strategy of power selling companies is more conservative under the confidence of 0.99, which belongs to the power purchase mode of risk aversion, and the power purchase strategy of power selling companies under the confidence of 0.95 belongs to the risk preference type. Comparing Fig 3 and Fig 4, the deviation of the two curves is large under different confidence. Under the similar expected rate of return, the conditional VaR with 0.99 confidence is greater than the conditional VaR with 0.90 confidence, which means that in more extreme cases, the power purchase decision of the power selling company may face greater risks. Compared with similar conditional VaR, the expected rate of return with 0.99 confidence is much lower than that with 0.90 confidence. The inflection point of conditional VaR with 0.99 confidence is also higher than that with 0.90 confidence, that is, high risk comes earlier. Compared with table III, near the conditional VaR of 0.22, the expected rate of return of 0.99 confidence is 0.2, while the expected rate of return of 0.90 confidence is 0.3. Compared with the two groups of power purchase schemes, the power purchase combination of 0.99 confidence is more conservative, and the power purchase proportion of power supplier 3 with high mean value and low variance is greater. For power selling companies with high risk aversion, they can choose higher confidence to reduce fluctuations in order to lock in risks; For generators with low risk aversion, lower confidence can be selected to increase revenue.

## V. CONCLUSION

In terms of power sales companies' participation in power purchase and sales transactions, most of the transactions of power sales companies belong to pilot transactions of medium and long-term contracts, and a completely spontaneous, efficient and real-time market has not yet been formed. In order to adapt to the fast and changeable wind power market, the power sales company also needs to further carry out the following work: the power purchase and sales strategy of the power sales company can be considered as a whole, take the profit of the power sales company as the benchmark, synchronously construct the bilateral strategy of power purchase and sales, learn from the experience of other industries, and innovate the power purchase and sales strategy on the premise of meeting the particularity of the power system. The high-precision load forecasting model is the cornerstone for the power selling company to adopt reasonable strategy judgment. The data model based on large error may lead to the misjudgment of the power selling company. Under the two-way trend caused by multiple factors such as a large number of new energy access and smart grid construction, the construction of basic technology of power sales companies is also particularly important. The acquisition of more and more accurate information is

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conducive to the long-term stable profitability of power sales companies. As an energy service industry, the power industry is gradually changing to the direction of multi energy supply. The future development direction of the power sales company is not only the provider of electricity, but also the provider of heating, refrigeration and other energy. In this case, the purchase and sales strategy of the power sales company will be more complex, and the model will also have a special situation that needs to be decoupled.

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